For Description See Chapter VIII.

Fig: 4.

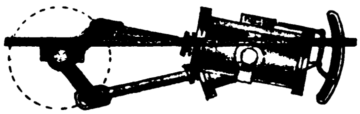


Fig: 7.

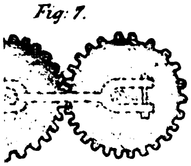
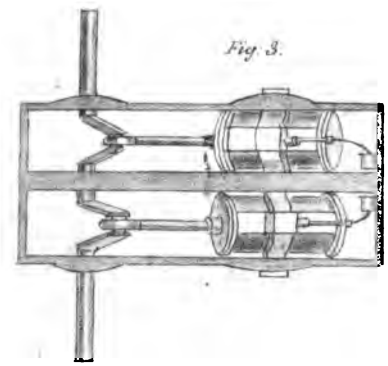


Fig: 3.



A TREATISE

UPON

ELEMENTAL LOCOMOTION,

AND

INTERIOR COMMUNICATION,

WHEREIN ARE

EXPLAINED AND ILLUSTRATED, THE HISTORY, PRACTICE, AND PROSPECTS

OF

STEAM CARRIAGES;

AND THE

COMPARATIVE VALUE OF TURNPIKE ROADS, RAILWAYS, AND CANALS.

Second Edition,

IMPROVED AND ENLARGED, WITH AN APPENDIX, AND A
NEW SET OF PLATES.

BY ALEXANDER GORDON, ESQ.,
CIVIL ENGINEER.

LONDON:
PRINTED FOR THOMAS TEGG & SON, CHEAPSIDE;
R. GRIFFIN AND CO., GLASGOW; WISE, TEGG AND CO., DUBLIN: ALSO, JAMES
AND SAMUEL AUGUSTUS TEGG, SYDNEY, AUSTRALIA.

MDCCCXXXIV.

LONDON:
PRINTED BY BRADBURY AND EVANS, WHITEFRIARS.
(Late T. Davison.)

PREFACE.

THE very favourable and flattering manner in which the original edition of this treatise has been noticed by numerous periodicals, at home and abroad, as well as by gentlemen who are well qualified to judge, induces me to venture again before the public, in a second edition, encouraged as I am, to hope, that I have not been altogether unsuccessful in awakening the public mind.

I have added so largely to some parts of my work, and made such changes in its arrangement,—advisable at this more advanced period of locomotive science, for rendering it of more value and interest to practical and intelligent readers,—that this edition may almost be considered a new book.

I have availed myself of the valuable labours of Mr. Grahame, Mr. Wood, Mr. Macneill, M. Gestner, and others, as well as of evidence adduced before the Select Committee of the House of Commons in 1831. It cannot be expected, nor is it necessary, that, in a treatise upon the entire subject of Locomotion, every line should be original. It has however been my endeavour to acknowledge the benefits offered by other writers whenever I have had recourse to them.

I have also availed myself of some articles which appeared in six numbers of "The Journal of Elemental Locomotion"—a periodical which was commenced and edited by me, with a view to open up more extensively the economical advantages attendant on this branch of practical science—which I have done with the less hesitation, as that periodical is now out of print.

Since this edition passed through the press, a Select Committee of the House of Commons has taken evidence upon Mr. Goldsworthy Gurney's claim for Parliamentary remuneration. How far that claim will be followed by a public grant is not yet known. The evidence adduced before that Committee is to much the same effect as many observations recorded in this edition. A short notice thereof is given in Appendix H.

It will be seen that the plates for the present edition are drawn anew, for the sake of more convenient arrangement, and drawings are inserted which could not have been published in this volume, had the old plates been retained.

In undertaking a disquisition upon Locomotion, during hours snatched from other professional pursuits, I pretend not to the niceties of literary composition, and expect not that my limited experience in correction of the press, is adequate to the prevention of typographical inaccuracies; I only pretend to the production of a work which may be considered *useful.* In a word, my professional habits called me to the task; and, believing that every man should attempt some good, and that by humble and oft-neglected means, "God in his goodness provides for the poor," I was roused to the contemplation, and encouraged to publication upon the subject, fraught as it is with such important benefits to man.

ALEXANDER GORDON,

CIVIL ENGINEER.

London, October, 1834.

PREFACE

TO

THE FIRST EDITION.

In the belief that a work upon *Elemental Locomotion*,—for the purpose of showing the utility, commercially, politically, and morally, of introducing it into general practice upon the highways of the United Kingdom, and how the knowledge and practice of mechanical science has brought this desideratum within our power,—is now required for the information of society in general, I venture, after eight years spent in anxious experiment and observation upon this important branch of mechanical philosophy, to publish the following Treatise, which pretends only to the name of a useful work; and is offered as such to the public with an earnest hope, that a subject of such vital interest may be taken up, and considered with the attention it deserves.

For endeavouring to open up, and call public attention to, a new path in Economical Science, admirably adapted to supplement artificially the livelihood, property, and happiness of the British Nation, and that at a moment when our natural resources have become totally inadequate for these purposes, I need make no apology. The subject has been deemed worthy of close investigation by the highest and most enlightened legislature in the world. And it is a field, beyond all others of a political kind, suited to the labours of the philanthropist.

London, April, 1832.

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ERRATA.

Page 34, line 4, *for* " Robinson" *read* " Robison."
55, 19, 29, *for* "Stevenson" *read* " Stephenson."
56, 7, 12, 16, *for* " Stevenson" *read* " Stephenson."
57, 1, *for* " Stevenson" *read* " Stephenson."
91, second line from bottom, *for* " Winson" *read* " Winsor."
138, line 23, *for* " Redman" *read* " Redmund."
139, 3, *for* " Redman" *read* " Redmund."
223, at the table, *for* " maintenance of 30 miles" *read* " maintenance of each *mile* of 30 miles."
257, line 15, *for* " fig. 14," *read* " Plate XIII. fig. 14."

LIST OF PLATES.

TREATISE ON LOCOMOTION.

CHAPTER I.

UPON THE MOST PROMINENT ADVANTAGES.

In a state of society so artificial as our own, the truism, that every increase of knowledge and adaptation of scientific discovery to the wants and the exigencies of human life, tend to lessen the labour, and to increase the comfort of man, affords one of the strongest consolations and encouragements to whoever directs his attention to the amelioration of his kind. That knowledge is power, has long been a favourite and prevailing maxim, as well in mechanical as in moral philosophy. The latter we have seen realised in the rise and preservation of numerous infantine states which it has cradled into greatness. We read the former in those mighty operations which make the winds and the waves obedient. That it is wealth and prosperity, a long course of experience equally testifies. But it has been reserved for it in latter times to achieve, in the outgrown relations of existing society, a more extended and beneficent direction as a *political* agent. The master-mind whose genius called into operation that mighty power,—the discovery of which in mechanics, in an age of inventions, stands out with as pre-eminent distinctness in the nineteenth, as the discovery of a new world illustrates the fifteenth century,—perhaps did not, in revolving all its varied and wonderful properties of scientific application, contemplate it in its highest result of all, the possibility, namely, of its conversion to *economic* purposes, sufficient to uphold and perpetuate the prosperity and happiness of the British Empire.

At a crisis like the present, when the country is labouring under the pressure of a redundant * and starving population, the subject which we are about to treat of, comes recommended with a peculiar emphasis. The substitution of inanimate for animate power, by which an increase of food, equivalent to the consumption of sixteen million of mouths,—which is equal to the addition of a territory double in extent to that of Ireland, possessing all its natural resources and fertility,—without the drawbacks of an unmanageable population, is a project, which bears on its surface, not the interests of a handful of individuals—a class of society—or branch of trade—but of the whole nation. How fortunate then is it, that it further comes with the recommendation, of not presenting itself in the doubtful guise of an expedient speculative question—but as a plain, practical, demonstrable matter of fact, realisable in operation, and determinate in result. This will appear in obvious sequence from the unvarnished facts which we now, in detail, proceed to adduce as proofs and illustrations of the truth of our position.

In a great complex question of this kind, involved, not in theory, but in what is equally disadvantageous, the doubtfulness and suspicion of a novel project,—where all the results lie so far beyond the ken of a bird's-eye esti-

* I use the word redundant as signifying, not superfluous, but flowing over any means yet adopted.

mate,—which is to trench in so many respects upon selfish relations,—and is to equalise the permanent prosperity of the multitude to the temporary inconvenience of the few, —it must ever be borne in mind, that to whatever point of detail we direct our attention, we shall perceive but a very limited view of the benefit, as a whole, which is to arise from the introduction of this grand agent, when it shall be properly economised, and brought to bear in full operation upon the varied transactions of daily life. We shall therefore confine ourselves, in this chapter, to a cursory estimate of a few of the leading *commercial* advantages which will accrue to the community by the substitution of inanimate or steam-power for animate or horse-power, for locomotive purposes: leaving it for a future chapter to show, as we shall attempt to do, the mighty amount of *political, agricultural* and *moral* advantages.

In a great commercial country like ours, extending its ramifications to every branch of natural and artificial produce, it is almost superfluous to remark that a vast capital is sunk annually in the mere transport of marketable commodities; and which is not only a loss to the seller, as being an unproductive outlay, but entails a heavy increase of expense to the buyer also, upon every article of daily consumption.

It has been well said by the Author of "Results of Machinery," that if there had been no roads and bridges on the line betwixt London and Edinburgh, a traveller would not accomplish the distance in less than six weeks. He would have to wend his way round hills, and to ascend rivers, until he found them fordable and safe; having crossed one stream, he might find another, which would require him to vary his course as many miles in an opposite direction; and at length, after a zigzag, backward and forward course, he might find himself at his destination. It is needless to observe that the conveyance of a ton weight of goods by such a route, would be almost impossible. We may not be able to prove the time at which such was the condition of our forefathers, but we can see the state of travelling in other countries. If we look to Colombia, which abounds with so many natural advantages of climate and production, we find the industry of that immense portion of the new world is almost unknown.—Scarcely a road is made, and, as might be expected, agriculture and manufactures, are in their primeval state; and those luxuries of life, which we reckon amongst our necessaries, the poor inhabitants are ignorant of. The dwellers in one province, are unacquainted with the produce of another province, and desolation in the midst of natural abundance, is the feeling of the civilised traveller.

The first good interior communication in Britain seems to have been at the time of the Roman invasion. Their military fastnesses were on the tops of hills, and connected with each other by direct, or nearly direct lines of road. The communication through those parts of the country which had no such roads, was maintained by means of saddle and pack-horses; and until within the last half century, there was no substantial improvement in the system, or at least no very obvious deviation can be traced. So late as fifty years ago, we find almost all the commercial transportations of this country, were carried on by similar means. Roads were certainly multiplied in number; but they are not worthy the name, when compared with those which the science of engineering has lately made us acquainted with, and which in the following pages, are more fully described. Such roads as then obtained, were not generally fit for good carriage conveyance.

If we consider Edinburgh to have been, in more barbarous times *six weeks'* journey from London, and to be now only *forty-eight hours'* journey, the distance from the one place to the other is reduced to one twentieth, and the traveller is consequently saved the other nineteen-twentieths of his time, and we may also say of his bodily fatigue. How much mental energy is saved to the country, we cannot pretend to estimate; still less can we reckon the mighty amount of moral strength and grandeur, which has followed by reason of that "concentration of mind and exertion," which thickly-peopled districts and busy populations always exhibit, and which improved conveyance is rapidly extending throughout the whole realm. Let us turn to the single instance of that mighty engine the "Times" newspaper, by which intelligence from every part of the world is made to burst upon us at our morning meal. We might be led to talk of the possibility that the eloquent pleadings for help to outraged humanity,—the echo of which has scarcely subsided in the Senate, ere we peruse it still wet from the press,—are presented to us on paper * which has once been pillowing the head of the oppressor, or stanching the blood of the oppressed; and we might be led to prove, that every line and every letter of all which has for years appeared from the pen of philanthropy, in behalf of the oppressed negro, has received its ink from that produce †, which has been wrung from the agonised labour of our fellow-man; and thus, what was said to be only obtainable by slave labour, has been the most active instrument in bringing about free labour. Suffice it to say, that every material which is

* Rags are imported from all parts of the world for English paper makers.

† Inking rollers are now universally made of glue and *treacle* mixed together.

used in the Times office, every tool which is employed, every channel of intelligence availed of, in fact every artificial production there,—either results from the immediate agency, is upheld by the influence, or depends upon, facility of communication. And it will be found that man has risen in the scale of created intelligence, in proportion as plurality of design and execution has by social and united intercourse, been made to advance in one vast and harmonious movement.

Expeditious locomotion, to the commercial world more particularly, in every mercantile transaction, is equivalent to capital; and such is the vast importance of economy of time here, that no extra expense is considered as too great to accomplish the utmost speeds. We have this practically illustrated in the preference which society gives to a complicated machinery put into motion at an enormous expense, to travelling by the winds of heaven which cost nothing. Nay, we have lately seen the speed of eight miles increased to nine, though purchased at an addition of *one-third* of the original outlay; and that again accelerated to ten, though it could only be effected by *doubling* the whole cost!

To the merchant, time gained is equal to money: for time occupied in travelling is just so much profitable employment lost. Time occupied in the transport of goods, is equivalent to so much interest of capital spent: for a thousand pounds invested in merchandise, is unproductive so many days as the transport is tedious. That part of the capital of an individual which is employed in the carrying of his goods to and from market, is so much abstracted from his means of producing more of the article in which he exerts his ingenuity and labour, whether it be in agriculture or manufacture.

Easy communication lessens the time occupied in the transport; and a saving of time shortens the distance, or our notion of distance. This effects a saving of money; and a saving of money, permits of a greater employment of capital. The man who can only afford to keep one traveller soliciting orders for his goods, will thus be enabled to keep two; because the expense of travelling will be reduced a half. Or it may be, he will find it more advantageous to employ the saving in the production of a more delicate and valuable article in the way of his trade. The increased traffic from place to place will give likewise a desirable impulse to business. The manufacturer in Scotland, will find the London market more easily arrived at; and the merchant in the metropolis, will find his orders more rapidly given and executed. A conveyance which, by good management, would be a weekly one, is, by bad management, a monthly one: and the carrier is obliged to quadruple his charge for the transport. To meet this charge, the merchant has to add to the cost of the article, and so on throughout the various gradations of mercantile transition, until the consumer pays the necessarily increased price. Hence, whatever reduces the price of transportation, reduces the price of the commodity transported. Whatever reduces the traveller's time, reduces his claim for compensation, and (competition being always at work) he is content with a smaller profit upon his merchandise. If a scarcity of any article occurs at one point of the kingdom, the monopolist there cannot continue his increased price for any duration of time. Commerce may, in this respect, be likened to water, for, if not obstructed, it will always circulate till it find its level. An opening or channel being furnished, an equalised supply will make its way wherever required.

Let us here take a slight retrospective glance at the road communication of Britain.

In 1678 the first coach was started from Edinburgh to Glasgow, a distance of forty-four miles, which distance was accomplished, to and from, in six days*. At the present period four hours and a half is all the time required to travel by coach from the one city to the other.

In 1706 the conveyance from London to York was by a stage coach, which was *advertised* to perform "the whole journey in four days†." This is now accomplished in twenty-four hours.

In 1712 we find, by an advertisement‡ in the Newcastle Courant, that the stage coach conveyed passengers between London and Edinburgh by means of "eighty able horses," in thirteen days, without any stoppages. But according to M'Culloch's Dictionary, there was only one coach, in the year 1768, which set out once a month, taking from ten to twelve days to perform the journey. Other routes were equally tedious§.

* In 1678 Mr. William Hume, merchant, Edinburgh, contracted with the magistrates of Glasgow, that he "should have in readiness a sufficient strong coach to run between Edinburgh and Glasgow, to be drawn by six able horses, to leave Glasgow ilk Monday morning, and return ilk Saturday night, God willing."

† Every Monday, Wednesday, and Friday (if God permit) it sets forth "at five in the morning, and returns from York to Stamford in two days, and from Stamford by Huntingdon to London in two days more, and the like stages on their return."

‡ "Edinburgh, Berwick, Newcastle, Durham, York, and London stage coach, begins on Monday the 13th of October, 1712. All that desire to pass from Edinburgh to London, or from London to Edinburgh, or any place on that road, let them repair to Mr. John Baillie's, at the Coach and Horses, at the Head of Canongate, Edinburgh, every other Saturday, or to the Black Swan in Holborn, London, every other Monday; at both which places they may be received into a stage coach, which performs the whole journey in thirteen days, without any stoppage (if God permit), having eighty able horses to perform the whole stage. Each passenger paying four pounds ten shillings for the whole journey, allowing each passenger twenty pounds weight, and all above to pay sixpence a pound. The coach sets out at six o'clock in the morning. Performed by Hen. Harrison, Robert Yorke, Richd. Speight, Richard Croft."

§ "A new post coach, hung on steel springs, with four horses and

"In 1760," says a writer in Pinnock's Guide to Knowledge, "when it was necessary for a journey to be taken from Brighton to the metropolis (a distance, *then*, of about sixty miles), the travellers, after breakfasting, dining, and supping on the road, were, by great exertion, able to get as far as East Grinstead (about thirty miles), where they stayed all night, and by persevering in the same manner the following day, were enabled to reach London at night, making the extraordinary journey of sixty miles in *two days*. These were the 'good old times.' Things are now strangely altered, and we are extravagant enough to perform the same journey (now reduced to fifty-two miles) in five hours, and sometimes less."

Now that Britain is the workshop of the world, and radiates the produce of her busy population through her every corner, and into distant lands, good communication is so necessary, that we can scarcely imagine ourselves bereft of it. The large capital sunk in mere transport, taken from the means of the agricultural, manufacturing, and commercial body*, is deeply felt by them, and consequently must be paid for in the price of every article of daily necessity. Any means, therefore, which will better and accelerate conveyance, bears on its surface a great gain to every individual throughout the community.

The rapidity of conveyance is another requisite to a healthy and prosperous state of society; for that which is

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two postilions, sets out from the Greyhound Inn, Market-place, Bath, and the George Inn, Drury Lane, London, every Monday, Wednesday, and Friday, at seven o'clock in the morning, and arrives at the above inns on the following days at four in the evening. The coach stops all night a Andover, going and coming."—*Newspaper*, 1765.

* Some of the large cotton houses in Manchester save nearly 800*l*. a year in carriage, since the opening of the railway betwixt that town and Liverpool.

to us of vital consequence to-day, will perhaps be of no use ten days hence.

How has the expedition of steam-boat conveyance increased the productive industry and happiness of the land? It has brought the Scotch farmers' cattle, fat and fresh, to the London butcher. It has brought the cotton manufacturer of Dundee nearer to London than the manufacturer at Manchester is. The northern producer and the southern consumer are closer together. Our notions of space, despatch, and distance, have been completely altered. Instead of measuring by miles, we compute by hours. Dublin is brought within eighty hours of London, instead of being sixteen days distant. Edinburgh is within forty hours of London, instead of being eight days distant: but we cannot enumerate the various radiating lines where London is the centre. These lines have all been shortened at least one half, and the energies of the kingdom are thus more compacted and concentrated.

The cheap and regular power of steam has enabled us to do this. Our aim is to increase the facilities of communication, by applying the steam-engine to this purpose on land. What England would now do without the steam-engine, it is impossible to say. Does not every one know, that, even within the last century, over a large tract of the island, the lesser proprietors, who all wrote *esquire* after their name, had nothing better for their holiday apparel than the hodden grey spun by their wives? Of the *un-inexpressible* condition of the lower orders, in those days of cold, privation, and nakedness, it were indelicate to speak. Our grandsires were not equally housed, and clothed, and fed as ourselves. Yet, should the query arise,—and it is not an uninteresting one,—what has enabled that class in society to wear two hats in the year instead of going bare-headed, or sporting the bonnet which their fathers wore—and clothed them in suits of excellent broad cloth, and given them to ruffle it with the first-born of the land; which has donned for their wives, ladies' apparel, made their boys rejoice in plurality of suits—and in the bridal hour busked their daughters in robes, delicate in texture as the spider's web, beautiful in colour as the rainbow's hues, and for elegance, such as never, in her grandame's younger days, even duchess wore; which plaited her bonnet, tamboured her net, wove her laces, knitted her stockings, veneered her comb, flowered her ribands, gilded her buttons, sewed her shoes, and even fashioned the rosette that ornamented their ties?—the answer is STEAM.

Considered in its application to husbandry; the cottager looks forth upon the neat paling which fences his dwelling—it was sawed by *steam*. The spade with which he digs his garden, the rake, the hoe, the pickaxe, the sithe, the sickle—every implement of rural toil which ministers to his necessities—are produced by *steam*. *Steam* bruises the oil-cake which feeds the farmer's cattle,—moulds the ploughshare which overturns his fields,—forms the shears which clip his flock,—and cards, spins, and weaves the produce.

Applied to architecture we find the Briarean arms of the steam-engine equally everywhere at work. Stone is cut by it—marble polished—cement ground—mortar mixed—floors sawed—doors planed—chimney-pieces carved—lead rolled for the roof and drawn for the gutters—rails formed—gratings and bolts forged—paint ground and mixed—paper made and stained—worsted dyed, and carpets wove—mahogany veneered—door-locks ornamented—curtains and furniture made, printed, and measured—fringes, tassels, and bell-ropes—chair-covers and chair-nails—bell wires—linens and blankets—china and earthenware turned—glass cut—and pier glasses formed. The drawing-room, dining-room, kitchen, pantry, closets, &c. all owe to *steam*, more or less, the most essential service.

In the year 1807, at New York, we, *in propria personâ*, saw Mr. Fulton first apply steam to external communication, by employing it to propel vessels: since then, it has acquired an importance which no one could have dared to anticipate. When we reflect upon the feeble efforts made even so shortly as ten years ago, we shall regard the contrast with pleasure and astonishment. In the shipping world, steam has wrought marvels; already it has revolutionised the ocean. After failures innumerable, and expenditure immense, at length the magnificent steam-ship has obtained the art of ploughing her unwearied way against wind and tide, and made herself the indisputable mistress of the vasty deep—the abridger of space—the economiser of time—the uniter of all lands! Created by steam—self-moved by it;—Steam likewise fashioned her ponderous anchors, rolled out her coppers, twisted her enormous cables, wove her broad canvas, and gives her "to walk the waters like a thing of life," the admiration of the world. At the present day the sea, and rivers, and lakes of the British empire, are covered with steam packets: to them now, almost exclusively, is intrusted the conveyance of passengers, and even a large part of our coasting and foreign trade. Our shipping list is thickly set with vessels propelled by steam: the capital embarked in them is immense. The passengers conveyed by one captain alone, during his command of a steam ship, on the Thames, have been upwards of 500,000, without one accident, in comfort, and at a considerable saving of time and expense.

Such are but a few of the numerous and important advantages which result from improved facility of communication, and from the substitution of elemental power for animal labour. But these, great though they be, are not so productive of that comfort to the humbler portion of the community, as we hope to show they may be rendered when steam carriages are brought into operation as *economisers of food.*

In a succeeding chapter this will be fully discussed; and we need only say here, shortly, that the great object for which we ventured before the public in a former edition—for which we were emboldened to appear at the lecture table, and to hazard the comforts of privacy in a public arena—has been and will be, the extended application of Steam to *economic* purposes, so as to counteract the evils attributed to its *physical* applications alone. For although the use of the steam-engine has cheapened every other necessary of life, it has not lessened the price of food. Although it has reduced the value of the poor man's labour (his only exchangeable commodity), it has not reduced the price of that for which he must labour.

We then flattered ourselves, that what we advanced, would associate with us, in the cause of forwarding the adoption of this great measure, not a few, whose enlarged knowledge would correct our inadvertencies, supply our deficiencies, and swell out our meagre outline of its estimated advantages, to their full extent; as well as engage the press and pen of the many philanthropists, whose breasts dilate in gladness over the beneficial effects of this noble project. Our hopes have not failed; many have rallied around us who stood aloof whilst the subject remained clouded with doubts and difficulties*.

It is not easy to separate the *agricultural, moral,* and *political* advantages, from the *commercial* advantages of steam carriages; yet, we shall not proceed farther in this branch of the discussion, until we have thoroughly

* See Appendix A.

established the practicability of the adoption of steam carriages for transport purposes.

We do not advocate any thing so preposterous as the change of the whole animate power of Great Britain at once into inanimate, though in this the political economist can see the solution of all our Malthusian difficulties. What we urge is merely the partial adoption of the thing to such an extent, as will relax the present pressure, and restore us to a wholesome state of national prosperity. This will occasion no dangerous experiment, and will be gradually followed up by a progressive conversion, by which all the conflicting interests of society will be neutralised, and the aggregate wealth, and prosperity and happiness of the empire be equalised.

If then *elemental locomotion* can be made to substitute the expensive, unproductive, *food-consuming* system of animate labour now in use, it will indubitably be for the vital interest of all classes of society that the substitution should be realised speedily and extensively.

CHAPTER II.

THE MEANS BY WHICH AN ELEMENTAL POWER IS OBTAINED AS A SUBSTITUTE FOR ANIMAL POWER.

THE source of steam, that elementary power which is now ready for our adoption in Locomotion, is heat. A limited quantity is generated by the combustion of a limited quantity of fuel; and if this can be embodied and suddenly abstracted, it can be made applicable to locomotion, or any other purpose of mechanical agency. It may, however, be embodied and produce a powerful effect, although it cannot be suddenly abstracted, but then of course it is not applicable to machinery.

A beautiful instance of this occurs in the preservation of the Conservatoire des Arts et Métiers at Paris, the walls of which had begun, owing to the weight of the roof, to recede from each other. Iron bars, with screws and dises on each end, were inserted and passed through both walls—the bars were heated, and in their expanded state, the dises were screwed up close to each wall. In cooling, an enormous power was exerted by the contraction of the bars, which drew the walls back into their proper position. And mention need scarcely be made of boiler and iron tank-makers, who always use their iron rivets hot, before rivetting the plates together by them. In every instance where iron is used as a means for bringing substances into close contact, this power, furnished by heat, is resorted to. It is impossible to deny that heat is the cause of power in the steam-engine; and that power is not in proportion to the quantity of heat generated, but to the quantity which can be embodied in a state disposable for use.

That state in which it is yet known to us, as most disposable for use, is when the heat has been imparted to water and formed into that aeriform state, known by the name of steam; which is, when unmixed with any other aeriform body, perfectly colourless;—when mixed with air, and thereby partially condensed, white and cloudy;—and when reduced to a temperature below the boiling point, again in its liquid state. The water exists in every stage of the process, and assumes the aeriform state only when a sufficient amount of heat has been imparted to it. The heat is the power separating the atoms. It overcomes the mutual attraction of the atoms for each other, and not only so, but it endows each of these atoms with a force of repulsion in proportion to the amount of heat. A low pressure or condensing steam-engine, by having the steam instantly condensed again into water, will illustrate this. Here the heat has entered the water, caused the particles to repel each other, and formed the steam,—and a cold application, depriving the steam of its heat (and causing them to attract each other,) instantly reduces the whole to water again. Now water of one bulk, say a cubic inch of water, when formed into steam, occupies 1700 cubic inches: and it is by throwing heat into the single bulk of water, thus increasing its bulk 1700 times, and then by abstracting that heat with a cold application, so as to reduce the 1700 bulks to one bulk again, that power is produced in the low-pressure engine. It is this generation and destruction of heat which produce the movement of dilatation and contraction: or to speak more correctly, of *repulsion* and *attraction*. A chemical movement thus obtained is easily applied in a machine by the engineer, so as to maintain the power which can " engrave a seal, and crush a mass of obdurate metal like wax before it; draw out without breaking, a thread as fine as gossamer, and lift a ship-of-war like a bauble in the air;" which "can embroider muslin, forge anchors, cut steel into ribands,"—and impel itself against the opposition of the very tempest.

Another mode of obtaining power in a steam-engine from heat imparted to water, is by *repulsion* alone, that is to say, by high-pressures; and it is this modification of the steam-engine which is used for steam-carriages.

A short description for the general reader may be deemed an essential part of a work of this kind.

All *high-pressure steam-engines* have a boiler, or generator of steam, and a working cylinder where the steam is applied; also a water-pump which feeds the boiler with a fresh supply of water, in the place of that water which is evaporated, and blown off into the atmosphere.

The boiler may be made in various ways, as will be seen in a subsequent chapter. By combustion of the coals, or other fuel in the fire-place, under the boiler, or by particular arrangement within or around the boiler, the heat is produced. Let us suppose the boiler to be a hollow sphere, half filled with water, under which the fire is made. The heat will pass into the water, and in a short time steam will fill the upper half of the boiler. If the boiler be open at the top, the steam will be seen to escape. The particles of water which have received the heat, have assumed a new character, and instead of *attracting*, they *repel* each other. If, now, the aperture be firmly closed, and the transmission of heat still be continued, more heat is imparted to the water and steam within, the forces of repulsion become more powerful, and when they are too powerful for the strength of the boiler to withstand (no regulated emission of steam being allowed, nor other provision for safety being made), the boiler will give way, or burst.

When boilers are made, it is usual to form them of such strength as will resist the pressures at which they are intended to work.

At first sight it would appear that high pressure steam is more dangerous than low-pressure steam. Whether it be so or not, there are some recently invented boilers which have reduced the chances of danger very much; even to that point where human life is perfectly safe. Of these boilers, we shall treat in a subsequent chapter.

There are steam-engines which work with thirty pounds pressure upon each square inch of the boiler: and there are some which work with more than two hundred pounds upon each square inch.

As that portion of the community who understand how a steam-engine is made a prime mover, is very small, I may be excused for unlocking the difficulty by a very simple key. A good lesson may be derived even from a trifle.

The pressure of the atmosphere is about fifteen-pounds upon each square inch whereon it acts, and the stream of steam which may be seen issuing from the spout of a tea-kettle, presses onwards by a little more power than the atmospheric pressure which would retard it. The pellet of chewed paper which a boy places loosely in a small tube, and blows from one end of the tube to the other by his breath, would be blown in a similar manner from end to end of a tube by the steam from the spout of a tea-kettle. By presenting the other end of the tube to the current of steam, the pellet would be forced back again: and so by presenting the ends alternately to the current of steam, an alternate rectilinear motion would be produced; in fact, a *pigmy steam-engine* would be the consequence. In this instance we have turned the ends of the tube to the steam where we required to reverse the motion of the pellet, but in the steam-engine of larger dimensions, we turn the current of steam to one or other end of the tube. The boy makes his engine by moving the tube to the steam: the engineer makes his, by moving the steam to the tube. The heavy iron tube, or cylinder, required for useful purposes, is in practice, generally kept at rest; in it a closely fitted piston travels from end to end, and the intensity and direction of steam are easily regulated.

In plate II., fig. 1, will be seen, the cylinder, and the arrangement by which the steam is directed to one or other end of the cylinder, forcing the piston, B, alternately backwards and forwards.

The steam from the boiler flows down A (fig. 1,) in the direction of the arrows, and forces the piston, B, along the finely polished cylinder, C; the piston pushing the aeriform fluid which is on the reverse side of the piston, and in the passage D, through E, and into the atmosphere, where it is dissipated. It will now be seen that the piston, B, has travelled from one end of the cylinder to the other. If we open the communication to the atmosphere at that side of the piston the steam has just been acting upon, by means of the slide, S, (more distinctly shown on fig. 6, where it is enlarged), which, at the instant of the change is slipped forward in such manner as to open the communication from F out to E, the steam will rush back along F, out by E, and cease to press upon that side of the piston. When this is done, the steam from the boiler is made to pass through A and D into the other end of the cylinder, and exerts itself in the contrary direction, forcing the *remaining* steam, from the other side, out into the atmosphere. The piston having arrived at the end of the cylinder, and the slide having been again shifted,—the steam from the boiler rushes through A and F to press the piston back again; the communication with the atmosphere being opened from the other side of the piston. By continuing this process we have the piston, B, forced alternately to one or other end of the cylinder, C; and so long as the boiler supplies steam, this alternating motion will be continued; the slide valves being shifted at each movement of the piston, so as to allow the steam to press on one side of the piston, whilst it allows the steam at the other side to rush off into the atmosphere.

But the shifting of this small slide is not a manual operation: the hand is only applied to it at starting or stopping the engine. When the engine is at work she opens and shuts for herself, in the following manner.

In order that no steam may escape past the piston-rod, G, where it travels out and in the cylinder, C, a small stuffing box is made at M, wherein a little hemp is closely pressed against the piston-rod by means of a screw, O. This pressure on the hemp may be increased or relaxed by merely adjusting the screw, O, which embraces the piston-rod. P is the parallel motion in which a wheel, Q, runs backwards and forwards. V V V is the valve motion which moves the slide valve, S, backwards and forwards, being operated upon by the eccentric wheel or shive, X, in its progress round Z, the centre of the crank shaft.

When the piston, B, is driven from one end to the other like a shuttle-cock, it will be obvious that the piston-rod, G, is driven with it. This piston-rod is connected by another rod, H,—which acting upon the crank, J,—turns it round, describing the dotted circle in the direction of the arrow. Thus, from the alternating rectilinear motion of the piston, a continuous circular motion is obtained. But it will be seen that when the crank, N, reaches in its revolution either of the two points K or L, there will be an uncertainty which way it would turn: it might falter and go back again. In stationary engines, a heavy fly-wheel helps the motion to continue over these centres, as they are called. In steam-carriages, however, the weight of a fly-wheel is so great, and the shocks to which it would be subjected are so numerous, that it cannot be used, and therefore two engines are applied to the same boiler; one engine always being in full force when the other is passing the centre—so that there is a continuous and unimpeded motion round the circle.

The power of the engine is calculated by the effect it produces in moving the piston at a given speed, from end to end of the cylinder. Suppose the steam from the boiler presses on the one side of the piston, B, with a force equal (say) to 50 lb. on each square inch, and the force of the atmosphere (15 lb. on each square inch) is all that opposes the movement of the piston; the difference betwixt the 50 lb. pressure of steam and the 15 lb. pressure of the atmosphere is 35 lb.; and if the area of the whole piston, B, be 50 square inches, we have a gross pressure of 2500 lb. to move the piston, B, up to the other end. When it arrives at the upper end, the slide is shifted so as to allow the steam to enter at the other side of the piston, to drive it back again. We have already shown how the steam below the piston is got rid of; it (amounting to 750lbs. pressure) rushes off into the atmosphere.

The number of horse power exerted by such a steam-engine is calculated thus.—Suppose the diameter of the piston to be 8 inches, and the length of the straight stroke which the piston makes 16 inches. Square the diameter ($8 \times 8 = 64$) and ascertain the cubic inches in (64) the square of the diameter, by multiplying that sum into ·7854—for as one is to ·7854, so is the square of the diameter to the area of the circle of which 1 is the diameter (1::7854::64:50). We thus find that there are 50 square inches of piston surface on which the pressure of 2500 lb. (or more or less, as the pressure may be) is exerted. Deduct the atmospheric pressure (50 lb.—15 lb. = 35 lb.) and we have 35 lb. of available pressure; which upon 50 square inches is = 1750 lb., which is the amount of power pressing the piston alternately in one or other direction. Now $2\frac{1}{2}$ miles per hour (or 220 feet per minute) is the speed at which one horse is computed to raise 44,000 lb. one foot high. Hence we have the amount of power to multiply into the speed (1750 lb. × 220 = (385,000lb.,) giving 385,000 lb., which divided by one horse's work, 44,000 lb. is nearly equal to 9 horses' work.

The *steam* blown away must be repaid to the boiler in *water*, which is done by a little pump worked by the engine.

There is in the steam-engine "a circulation like that of the blood in the veins of animals, having valves which open and shut in proper periods; it feeds itself, evacuates such portions of its food as are useless, and draws from its own labours all which is necessary to its own subsistence."

To all boilers there is one or more safety-valves, having weights or springs on them. Say in the present instance that the area of the valve is one square inch; then the weight on it must be proportioned to the power to be worked with. It will easily be seen, that if by neglect or any other cause too much steam or too great a pressure of steam should accumulate in the boiler, this valve will rise, the steam will blow away, nor will it shut again so long as the steam is at a pressure above that to which it is regulated.

Many attempts have been made to obtain the continuous rotatory motion of a piston in a cylinder, instead of the alternate rectilinear motion which has hitherto been used for the steam-engine as described above; and it may be said that from the time of Mr. Watt's first grand improvements to the present day, the ingenuity of mechanics has been stretched to obtain so great a desideratum. Of the many rotatory engines, however, none have stood the test of long trial; and indeed as yet there is none in *practical use*, if we except that of the Earl of Dundonald (the gallant and ingenious Lord Cochrane), which bids fair to rival the best reciprocating engine. This rotatory engine having been applied by his lordship to a small experimental steam-carriage, is, in consequence of such application, entitled to our notice. The locomotive carriage was never completed, and this engine had not in that instance a fair trial. The boiler, which was constructed upon Messrs. Ogle and Summer's principle, described hereafter, was imperfect, and the engine was removed from the carriage into a boat, as a more advisable field for exhibiting its qualities, which are admirable. The cause of uniform failure of other ingenious persons in the construction of rotatory engines, has been the difficulty of obtaining within the machine a base of resistance on which the steam might act in propelling the moveable piston. The means by which this has hitherto been attempted have consisted of a variety of very imperfect mechanical contrivances, all of which have proved quite inadequate to the successful employment of this sort of engine; but in the revolving engine now under notice, this difficulty is completely overcome. This engine is constructed on a principle that gives a perfect fulcrum or resisting base; indeed it is as perfect, and nearly as simple, as the fixed covers or heads of the cylinder in ordinary reciprocating engines. In plate II. are exhibited views of this rotatory engine: fig. 2 is an elevation; fig. 3, the longitudinal section, with the blade or piston, A, in one part of its course (a lunette space). Fig. 4 is a cross section, showing the blade or piston, A. Fig. 5, shows the piston in a different part of the lunette space. The same letters refer to the same part in each of the four figures where they are to be found. F is a *fixed* centre, or axle upon which the piston, A, turns; the radius sweeps round the inside of the larger circle, DD; G is the mathematical centre (for there is no axis through the centre of the inner cylinder, CCC, &c.) around which the cylinder, CCC, turns. The piston, A, works in a ball-cock or stuffing at B, and in traversing the lunette space, formed between

DD and CCC, is obliged to slide out and in through B. At one time this piston, A, will have a larger portion protruding from CCC, as in fig. 4, and at another time it will protrude less, as in fig. 5. At one time, in each revolution, it will be at a point where there is no part protruding. The piston crawls out of and into the cylinder CCC (through B) constantly.

The steam from the boiler is admitted through the hole, S, and rushes along the opening, Y, in the direction of the small arrow; it cannot escape where the cylinders, C and D, are in contact, and therefore it forces round the piston, A, in the contrary direction. The other part of the lunette space evacuates itself in the direction of the double arrows. Of course the power of the engine is always varying, because the surface of the piston is always either increasing or diminishing. To compensate *for this* variation, two cylinders are used; the one to be in full activity, whilst the other is passing the dead point. As the one decreases the other increases, and thus a continuous and uniform rotatory motion is maintained, which can be applied in every case where the reciprocating engine is used for rotatory purposes.

By some recent alterations in the steam ways, the patentee has been enabled to use two pistons in one cylinder, and thus to save weight to a still greater extent. By this new arrangement one piston increases in power in proportion as the other diminishes in power.

The great and paramount difficulty of obtaining a suitable fulcrum, having thus been completely overcome, all other obstacles to the employing of this sort of engine at once disappear; in truth, from the result of numerous trials during two years' experience, it may be affirmed that this engine is constructed in such a manner as to render it equally perfect and efficient as the best reciprocating engine.

Having said that it is, as regards its efficient properties, quite equal to any other, a few additional observations are here offered to point out some of the important advantages which render the revolving engine superior to the reciprocating engine, more especially for locomotive purposes.

It does not occupy nearly so much space as is required for the reciprocating engine. It does not require any valve or slide, and there is no loss, as in the space left at the top and bottom of reciprocating engines. There is much less friction than arises from the sum of all the bearings required, to convert the rectilinear force of the reciprocating engine, into circular motion.

There are no cranks, connecting rods, parallel motions, levers, slide-valves, eccentrics, &c., with their nicely adjusted joints and bearings; therefore, it is liable to fewer accidents and hinderances than other engines. The working of the rotatory engine is free from the tremor occasioned by the alternating of a mass of moving matter, twice in every stroke of the reciprocating engine.

As the moving parts pursue their course in perfect circles (without stop or hinderance), this engine is capable of a progressive acceleration, far beyond what durst be attempted with a reciprocating piston.

The diminished bulk, weight, and absence of tremor, will add to the capacity, velocity, and durability of carriages in which the rotatory engine is placed.

The practical reader will at once say these advantages are in obvious sequence, *when* a good rotatory engine is obtained; and without doubt the Earl of Dundonald has gone far to convince old and prejudiced engineers that the engines which Messrs. Seaward have constructed for him, are successful. Having seen many trials of them, and having accompanied his lordship very often in boats propelled by them, my own mind has been so far made up regarding their practicability and economy that I have ventured thus to recommend this rotatory engine.

There are other rotatory engines, and amongst them a very beautiful one invented by Mr. Robert Stein of Edinburgh, which is being rapidly brought to the test of regular duty.

The speed at which a reciprocating engine may have its piston to travel, has been, by common consent of engineers, limited to 220 feet a minute, or about two miles and a half per hour. And by this rule an engine making a stroke sixteen inches long (plate II., as in fig. 1,) will require wheels of large diameter to travel along the road at a good speed of ten miles an hour. Whilst this engine (plate II., fig. 1,) is causing her crank to travel round the dotted circle, LK, at thé above regulated speed of two miles and a half per hour, each turn of the crank, J, causes one turn of the hind wheels upon the locomotive carriage. If the engine work round this circle of forty-eight inches, LK, with a power of eight horses in thirteen seconds, it will work the hind wheels round a circle of one hundred and ninety-two inches with a power of two horses, also in thirteen seconds of time. The circumference of the hind wheels, travels through four times the space in the same time. Thus it will be seen that a lever of the third order is acted on by the steam-engine. A *loss of power* from eight horses to two horses has attended this *gain of speed.* The same design for obtaining a rapid motion is apparent in physiology; almost all the moveable bones of animals* being levers of this order.

In practice, steam-carriage builders have ventured to drive their pistons at a greater speed than two miles and a half per hour; some with whom I have travelled have driven the pistons nearly five miles per hour; and indeed it is now very generally considered by engine makers that the speed of the piston may be increased much beyond the

* Borelli de Motu Animalium.

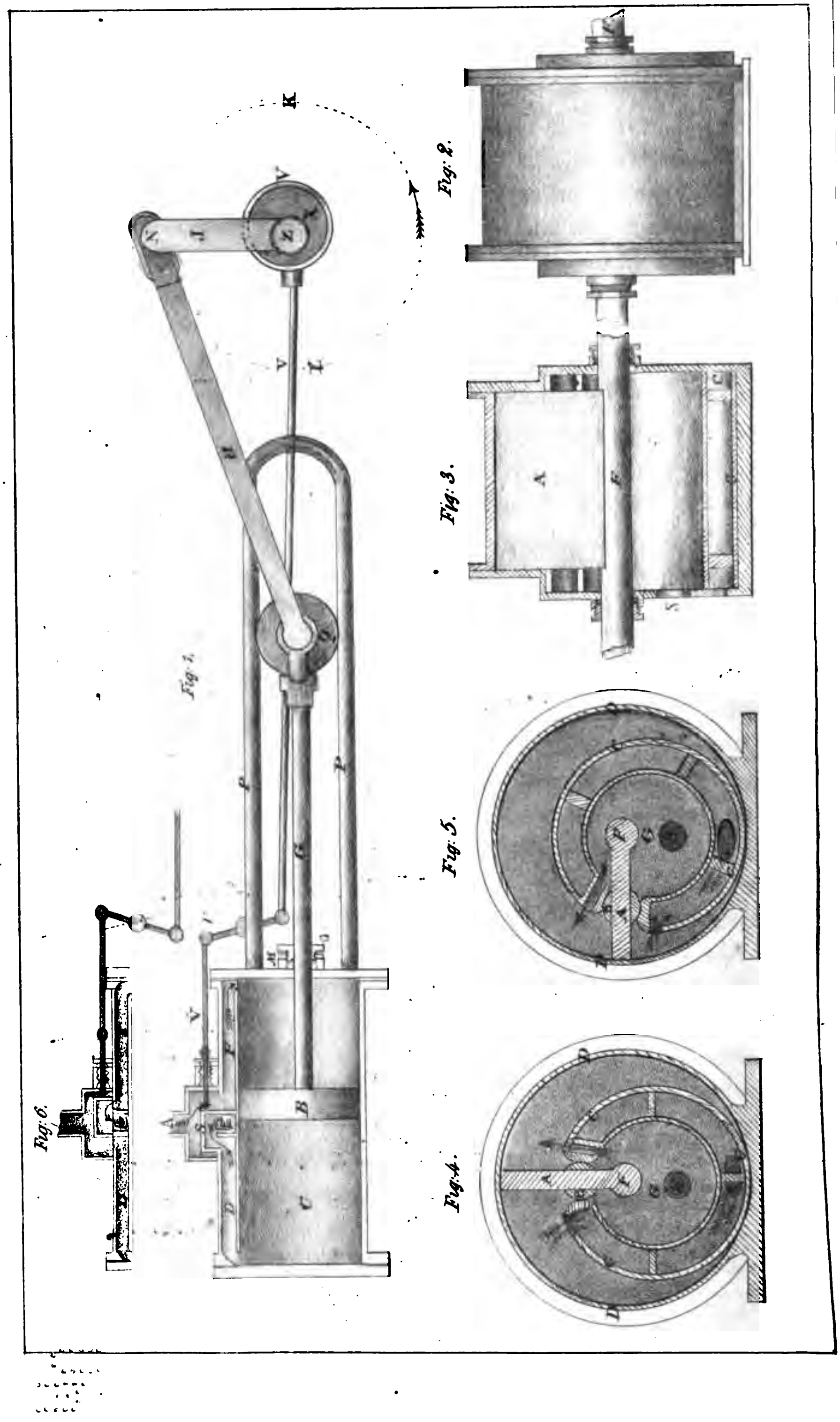
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.

old rule of two miles and a half per hour, provided the steam ways are constructed of sufficient size. A rotatory steam-engine will, in this particular, have a great advantage over the reciprocating engine.

The late Mr. Murdoch, of Soho, made several calculations and some experiments for a locomotive engine, in conjunction with the late Mr. Gordon, in the year 1819, for the purpose of introducing compressed air as the immediate motive power for carriages. But the compression of aeriform fluids was then in its infancy, and they were on that account discouraged in their proceedings. Their object was to store up power in the elastic air, compressed highly, and to let it down into a piston-engine by degrees, instead of steam. This may be more easily explained to some readers by the example of a watch or time-piece, in which the power of the winder's hand is stored up in the spring, and allowed to unwind itself, and to operate by degrees in making the watch go.

If we squeeze a sponge which is in good condition, we squeeze out the air contained in it; and when we relax our grasp, the sponge again distends itself and fills its cells with air. Suppose then that we squeeze or compress a cubic foot of air by an apparatus made for the purpose. In so doing we squeeze out the latent heat contained in that cubic foot of air. Still continuing the pressure, we force out more heat. The cubic foot of air is now reduced, say to one-thirtieth part of its original bulk. But as this is an unnatural state for it to remain in, there is a tendency in it to dilate in proportion to its density. Care must be taken to keep it tightly pent up, until the power thus stored is wanted.

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* A more philosophical description might have been given by treating heat as a property of matter, which varies with the state of pressure to which that matter may be subjected.

When we wish to use this power, we allow it gently to escape, which it will do at any opening, however small. It expands instantly, satisfying its avidity for the heat formerly forced from it, as it expands, by taking heat from surrounding objects, and the circumambient air. Thus a power is got, which is the movement from a state of compression to a state of dilatation—a movement somewhat similar to the expanding motion of high-pressure steam, described above.

The apparatus which compresses this air is kept cool by cold water externally applied, otherwise the quantity of heat forced from the air would make the pumps red hot. So also the expansion of the air must be well provided for, otherwise the cold produced is so intense that the machinery may be clogged up by a deposition of ice or snow. The surrounding atmosphere, robbed of its heat by the expanding power, deposits its moisture in a state of ice or snow.

This would be an interesting subject to illustrate farther by a variety of phenomena, which the extensive compression of carburetted hydrogen gas and atmospheric air by the late Mr. D. Gordon have made us acquainted with; but at this early stage of experiments upon locomotion by compressed air, such is unnecessary. Hitherto, all attempts to get a profitable and economical reaction have been unavailing.

Certainly a store of power carried in this manner would be of very great advantage, where the steam-engine itself may be objected to. It would be a noiseless and agreeable motive power for locomotion, in crowded streets and pleasure rides.

It is believed that Mr. Medhurst, who obtained a patent in 1799, was the first to propose working machinery by means of compressed air; but at that period the compression of air was ill understood, and had not been practised to any extent. Mr. Lemuel Wright obtained a patent in April, 1828, for the application of compressed air to work machinery; and Mr. Mann obtained a patent in 1829, for applying compressed air as the motive power of carriages; but there has as yet been no scheme for using compressed air, made public, which can be safely engaged in.

An engine, which created considerable interest in 1824 and 1825, was invented by Mr. Brown of Brompton, named a gas-vacuum engine, in consequence of a partial vacuum being formed by the combustion of carburetted hydrogen, or any other combustible gas and atmospheric air. The inventor applied the effects of the vacuum thus produced to the movement of a piston in a cylinder, and he deemed it particularly available for the purposes of locomotion. A power was got in a piston-engine, and a locomotive carriage was, on more than one occasion, propelled for some distance by this engine. Small paddle-boats were also exhibited on the Thames; but the use of the piston-engine seems now to be abandoned by Mr. Brown.

As a machine for raising water it has been more prosperous, although in its most perfect state far inferior to the steam-engine, on account of the expense of the gas required.

Some notice of this engine comes within our province: the late Mr. David Gordon, the inventor of the portable gas apparatus, and of two locomotive engines, described hereafter, impressed with the great importance of locomotion, originated a society of gentlemen in 1824, "tending to the ultimate establishment of a company for the purpose of contracting to run the mail-coach and other carriages by means of a high pressure steam-engine, or of a gas-vacuum or pneumatic engine, supplied with portable gas."

The committee of that society had only a limited sum at their disposal; nor were there to be more funds until a carriage had been propelled for a considerable distance at the rate of ten miles in an hour. Mr. Gordon soon saw that his expectations, in regard to the gas-vacuum engine, had been too sanguine, and immediately endeavoured to get the committee to proceed with a steam-engine. This unfavourable view of the gas-vacuum engine was formed from seeing the quantity of gas required in the engine's working, and from the expense of compression to render the gas portable. If the expense of compression can be borne, we conceive it will be for the purpose of high pressure air, in which case the carriage will be propelled by the expansion of the compressed air into the piston cylinder, as above described. Calculating the value of coal gas to be three shillings per 1000 cubic feet (and it is the cheapest gas), the expense of this engine is very greatly beyond that of a steam-engine. If it were used as a piston-engine for locomotion, the gas would have to be compressed into the portable shape, which would add, at the very least, three shillings and sixpence per 1000 cubic feet more.

Various schemes have been proposed for using gunpowder as a portable and powerful first-mover; but the danger of gunpowder, and its very great expense, except when used for projectiles, are sufficient reasons for abandoning the hope of its being made available for locomotive purposes.

In March, 1831,—I proposed to several military engineers the extension of the beautiful and accurate science of projectiles for the purpose of inland communication; and my MS. was about that time recorded in the library of the Royal Engineers at Chatham. Its title was, "Message-shells, a substitute for the telegraph and mail:" and my object was the projection of elongated cylindrical hollow shot, by parabolic curves, three miles at their base. The shells were to contain letters and despatches.

Many experiments have been made for the purpose of obtaining some other liquid than water, which could at a lower temperature and cheaper rate be converted from the liquid to the aeriform state, and again condensed by the application of moderate cold; and in the Philosophical Transactions, 1823, will be found some interesting papers by Mr. Faraday, and also by Sir Humphry Davy, who had in view the generation of different gaseous bodies under pressure, with the hope that, from the facility with which their elastic forces might be diminished or increased, by small decrements or increments of temperature, they would be applicable to the same purposes as steam. Mr. Faraday ascertained that the vapour from fluid carbonic acid exerted a pressure of thirty-six atmospheres, but says, that the application of such a gas as a mechanical agent will be attended with some difficulty; and in his paper, read before the Royal Society, he says, " The small differences of temperature required to produce an elastic force equal to the pressure of many atmospheres, will render the risk of explosion extremely small; and if future experiments should realise the views" developed in that paper, "the mere difference of temperature between sunshine and shade, and air and water, or the effects of evaporation from a moist surface, will be sufficient to produce results" equal in effect to the steam-engine.

About this time Mr. Goldsworthy Gurney, who had stated, in his public lectures on the elements of chemical science, in 1822, that "elementary power was capable of being applied to propel carriages along common roads with great political advantage, and that the floating knowledge of the day placed the object within our reach;" seeing the accounts of such experiments, and with the view of satisfying himself, and showing the true bearing of such propositions, in the institution with which he was connected, made a course of experiments, in which he found that ammoniacal gas was manageable. This gas, like steam, being absorbable in water, under reduced temperature and pressure, and being given out again with considerable force by heat, offered properties available for a motive power, capable of being worked with the ordinary apparatus of the steam-engine, or at least without requiring much alteration or change in the mechanical arrangement; and he constructed a little locomotive engine which acted by this power with great regularity. This experimental apparatus was eventually made the basis of a steam-engine, with which his first experiments in locomotion on common roads were made.

In 1825 Mr. Brunel obtained a patent "for certain mechanical arrangements for obtaining powers from certain fluids, and for applying the same to various useful purposes." He gave the preference to carbonic acid gas. Still, there was the great mechanical difficulty attendant upon the high-pressure of 30 atmospheres, *above which* his engine must work. No machine yet made could keep sound and free from leakage at such a constant pressure.

From these experiments, however, we may infer, that ere long the vapour of ammonia may be successfully brought into use as a prime mover.

Hot Air Engines.—Mr. Samuel Crossley, some years ago, exhibited an engine which produced a motive power by heat imparted to and abstracted from air. Many others have attempted to use heated air as a prime mover, but none so successfully as Mr. Erricsson, whose "Caloric Engine" has recently formed so interesting a subject of discussion among philosophers. A very concise and distinct account of this "Caloric Engine" has already been published by Mr. Erricsson, and we shall here merely refer inquirers thereto, and to the Mechanics' Magazine, No. 535.

Electro-magnetism has not yet been made available for any practical purposes of motion. Many beautiful philosophical arrangements have of late attracted the attention of men of science: they are all however nothing more than models for the lecture-room, or philosophical toys. The novelty of the facts are such, that certain charlatans have already begun to draw the purse-strings of credulous moneyed men. Truly the less one understands of a subject, the more is he liable to admire the mystifying talents of a mere juggler.

A careful perusal of recent discoveries in this branch of science will be amply rewarded by a glimpse of that field which it brings the reader in sight of. Electro-magnetism is a powerful agent, and forms an interesting study. Those who are looking forward to, and honestly pursuing it as a prime mover, may be too sanguine; nevertheless, amidst the wilds of fancy, there are often flashes of intelligence, which brighten up surrounding objects, and the philosopher is roused to the contemplation of splendid realities, which ultimately may be found practically useful.

Meantime we have a safe, economical, and certain power in the steam-engine, sufficient for the extensive operations of steam-carriages which we contemplate.

CHAPTER III.

THE RISE, PROGRESS, AND DESCRIPTION OF STEAM-CARRIAGES.

So early as the year 1759, Dr. Robinson, (subsequently Professor of Natural Philosophy in the University of Edinburgh,) then a student at Glasgow, threw out the idea of applying the power of the steam-engine to the moving of wheel-carriages.

In the year 1772, Oliver Evans, an ingenious American citizen, then apprenticed to a wheelwright, laboured to discover some means, other than animal power, for propelling land-carriages. He was, accidentally, made acquainted with the power with which steam is generated from a small quantity of water in the breech end of a gun-barrel, plugged up tight, and placed in a smith's fire. He was fortunate enough to find a book describing the old atmospheric steam-engine, and was astonished to observe that the steam was only used to form a vacuum, instead of being rendered available by its elastic power. Amidst much ridicule, he confirmed his discovery by experiments.

"In the year 1786, he petitioned the legislature of Pennsylvania for the exclusive right to use his improvements in flour-mills, and his steam-waggons, in that State. The committee, to whom the petition was referred, heard him very patiently while he described the mill improvements; but his representations concerning steam-waggons made them think him insane. They, however, reported favourably respecting the improvements in the manufacture of flour, and passed an act granting him the exclusive use of them as prayed for. This was in March, 1787; but no notice is taken of the steam-waggons."

A similar petition having been presented to the legislature of Maryland, that legislature, upon the argument that the grant could injure no one, conferred upon Evans, for a term of fourteen years, after 1787, the exclusive right of making and using steam-waggons in that State.

Although it does not appear that any thing, more than a good high-pressure fixed engine, resulted from his labours, we cannot omit a very striking prediction in the work of this great projector. "And I verily believe," says he, "that the time will come when carriages propelled by steam will be in general use, as well for the transportation of passengers as goods, travelling at the rate of fifteen miles an hour, or 300 miles a day, on good turnpike-roads."

In the year 1784, Mr. James Watt took out a patent, amongst other improvements of the steam-engine, for a mode of applying it to wheel-carriages.

In the year 1786, or 1787, Mr. William Symington, for whom there has been made reasonable claim to be considered the original inventor of the steam-boat, exhibited the model of a steam-carriage in Edinburgh. He appears to have designed the use of a condensing or low-pressure engine with one cylinder for this purpose.

In the year 1802, Mr. Richard Trevethick invented a high-pressure steam-engine and boiler in one machine, of a very compact and complete kind.

Plate III. fig. 1 and 2, gives a side and end view of this invention on four wheels. The boiler was made of cast-iron, and had the fire-place in the interior of it. Into the boiler, B, at one end of it, was fixed the cylinder; and the steam being supplied to the engine as described above, in wheel, A, is easily traced—tooth after tooth imbedded itself in the cavities of the toothed rail, and a hauling forward was the consequence.

The use of two engines (I mean of two cylinders and two pistons) is, that where one piston is just finishing its upward motion is ready to go down, and inclined to falter, the other piston is in full play upwards; and both being connected, the faltering of the one, or tendency thereto, is corrected by the other.

The rack-rail was only on one side of the way. The boiler was placed and rested on four bearing wheels. J is the fire-door, from which a hollow tube (containing the furnace) goes through the boiler from end to end. K is the chimney.

Messrs. William and Edward Chapman took out a patent in 1812, in which they specified the machine, Plate III., figure 4. The weight was distributed on eight points (instead of only four,) which, on a plate railway, or weak railroad, was an advantage. The beam and its corresponding piston, in the upward and downward motion on a fulcrum (a fixed point), worked the connecting rod, D, which was attached to a crank-arm. The revolutions of this crank-arm were attended by corresponding revolutions of the toothed wheel, F, which was on the same centre. And the drawing exhibits the working of F into G, and from thence to the spindle or axle of each pair of wheels.

Mr. Brunton, of Butterly iron-works, seeing the difficulty of others, struck out a new plan altogether, by which he arrived at a substitute for horses' legs. The piston-rod, A, of the engine, Plate IV., fig. 1, in its outward motion, forces out the leg and foot, B, which pushes behind; at the same time, the alternate motion of a horizontal toothed wheel, C, above the boiler, works in a rack on the rod, D, and thus pulls in the leg, E. When the piston-rod, A, travels back, the leg, B, is lifted back; and

Plate 3.

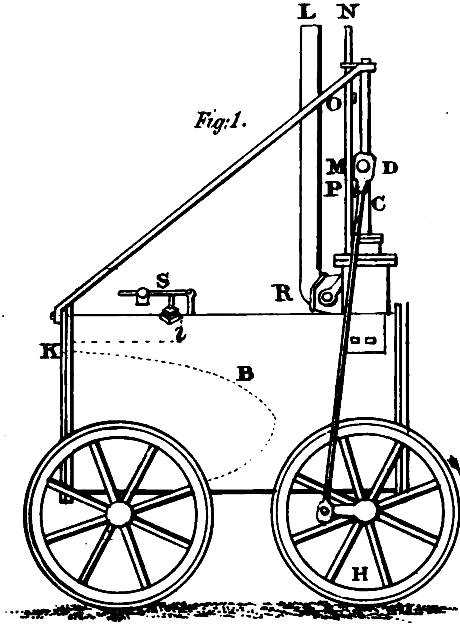


Fig: 1.

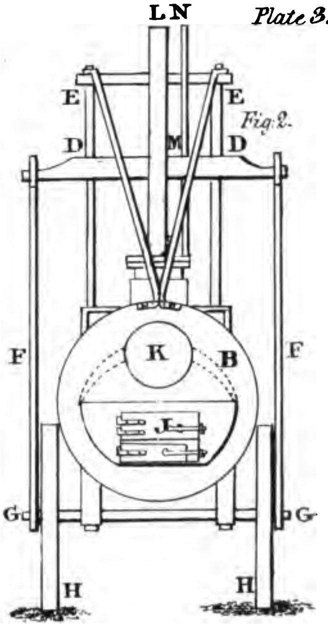


Fig: 2.

Fig: 3.

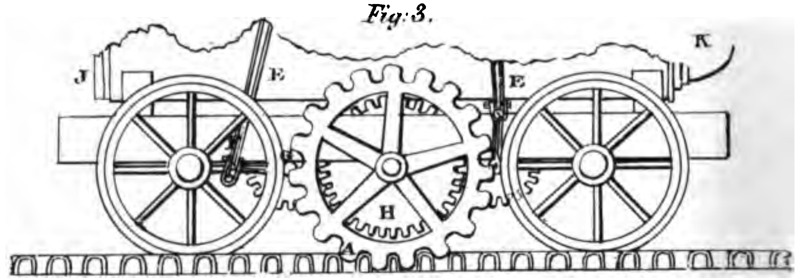
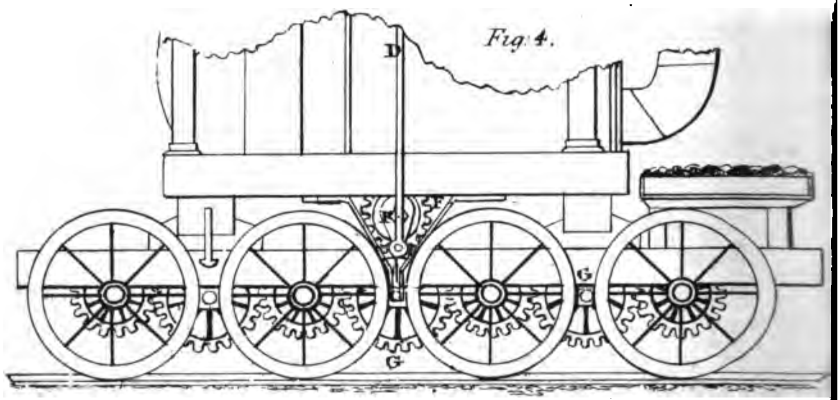


Fig: 4.



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the same returning stroke of the engine forces out the leg, E, in its turn, by means of the toothed wheel above.

A lamentable accident from the cast-iron boiler stayed Mr. Brunton's exertions. Mr. Brunton, however, fully proved the capabilities of such a locomotive engine with legs, both at Butterly and at the Crick lime-works.

At Killingworth colliery, in 1814 and 1815, Mr. George Stevenson, engineer to the Liverpool and Manchester railway, constructed several engines, of one of which a side and end view is given in Plate IV., fig. 2. There were two cylinders, and the motion was given to the wheels in a manner similar to Trevethick's engine (Plate III.) But here Mr. Stevenson obtains the friction of four wheels at the same time; and the pistons in A and B work simultaneously, the front and hind wheels which they act upon being connected by their axles, on which there is an endless chain, C, working on D D. The revolutions of the axles of the wheels, cause the valve connexions, E E E E, to be worked by the eccentric F and its fellow eccentric. The pump, G, is worked by the up-and-down stroke of the piston-rod. H, the fire-door. J, the ash-pit. K, the chimney; the fire-place and flue being through the inside of the boiler, and surrounded by water. L L are cylinders, of which there are four. In these, four pistons work, and the pressure of the steam on their upper side forms a spring of superior kind, to preserve the engine from concussions.

This was the most perfect railroad engine at work until 1830, when Messrs. Stevenson and Co. produced engines on the Liverpool and Manchester railway, which have surpassed Mr. S.'s former works.

A locomotive engine, such as this, is stated in Mr. Wood's first edition of a Treatise on Railroads to have weighed 6½ tons; and containing one ton of water, equal to 7½ tons, " it dragged twelve loaded carriages, each weighing 9,408 lbs., up a plane ascending 134 inches in 1,164 feet, and also the conveying carriage, weighing 1¼ tons, the wheels not slipping, the rails dry."

"The same author also gives the following experiments made on the Killingworth railroad:—The length of plane was 2,260 yards, with an ascent in one direction of 6 feet 5 inches, not uniform, varying from a dead level, or slightly undulating, to an ascent in one place of 1 in 330. Edge-rail, 2½ inches broad on the surface; carriages all the same construction, weighing 81¼ cwt. each, wheels 34 inches diameter, axles 2¾ inches diameter.

"*Experiment* 29.—Wheels, three feet; nine carriages, weighing 731¼ cwt., were drawn up the plane fourteen times in 317 minutes, and fourteen times down the plane in 258 minutes; distance traversed, 36 miles in 9 hours 35 minutes; coals consumed, 2,534 lbs.; water, 890 gallons.

"*Experiment* 30.—Wheels, four feet; nine carriages, weighing 731¼ cwt., were drawn up the same plane nineteen times in 302 minutes, and nineteen times down the plane in 265 minutes; distance traversed, 48·8 miles in 9 hours 27 minutes; coals consumed, 2,534 lbs.; water, 854 gallons.

"*Experiment* 31.—Wheels, four feet; twelve carriages, weighing 975 cwt., were drawn up the plane nine times in 155 minutes, and nine times down in 133 minutes; distance traversed, 23 miles in 4 hours, 48 minutes; coals consumed, 1,546 lbs.; water, 452 gallons.

"*Experiment* 32. (With a different locomotive engine.) —Wheels, three feet; nine carriages, weighing 731¼ cwt., were drawn up the same plane ten times in 212 minutes, and ten times down in 180 minutes; distance, 26 miles; time, 6 hours 32 minutes; coals consumed, 1,487 lbs.; water, 490 gallons.

"*Experiment* 33.—Wheels, four feet; twelve carriages,

Plate 4.

Fig: 1.

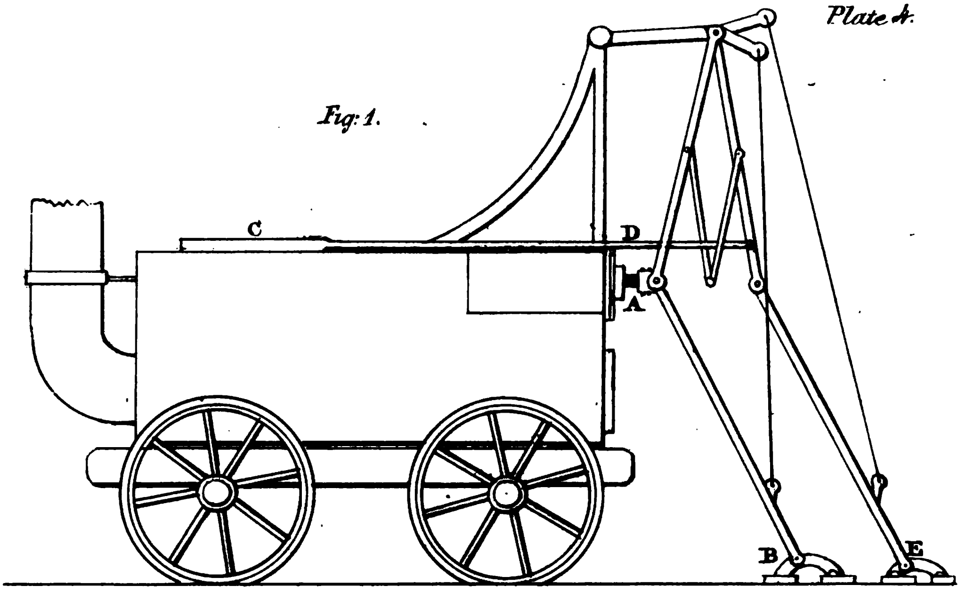
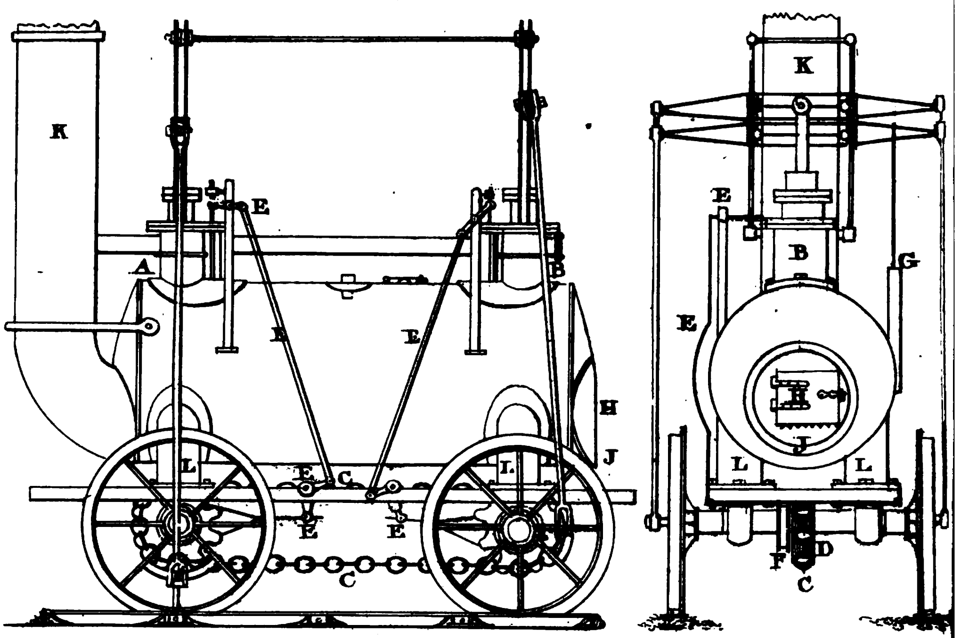


Fig: 2.



weighing 975 cwt., were drawn up the plane five times in 45 minutes 48 seconds, and five times down in 40 minutes, 26 seconds; distance each journey, 2,002 yards; total 11·375 miles; distance passed over in the above time 1,663 yards each journey, or 9·45 miles; time, 1 hour 26 minutes 14 seconds; coals consumed, 587 lbs.; water, 200 gallons.

"In this experiment the engine was allowed to traverse a given space, to put the train of carriages into their proper velocity before the time was noted; the time was then marked until the velocity was again checked at the farther end of the stage. This will explain the difference between the two distances stated in the experiment; the one was the whole distance from the commencement to the end of the stage; the other was that part of the stage which the engine passed over when the regular velocity was acquired, and before it was again diminished at the end of the stage, to stop the train; the time given was that which transpired while the engine was passing over that space, while the velocity was uniform, and may therefore be taken as a measure of speed.

"At page 281, Mr. Wood states, upon a railroad near Newcastle, a locomotive engine in fifty-four weeks conveyed 53,823 carriages of coals, each weighing 9,438 lbs., 2,541 yards, and returned with the same number of empty carriages, each weighing 3,472 lbs. This was in fifty-four successive weeks, and, in that time, exclusive of Sundays, the engine, from want of goods to convey, was at least twenty days off work; so that in 304 days the performance was 446,815 tons conveyed one mile; or 1,470 tons one mile each day on a stage only 2,541 yards. The engine had three-feet wheels, which were calculated for a rate of about $4\frac{1}{2}$ miles per hour.

"Mr. Rastrick, in his report to the directors of the Liverpool and Manchester railway, dated January 1829, gives the following table of the absolute quantity of work done by five different locomotive engines, when all reduced to the same standard of five, eight, and ten miles per hour. The carriages proportioned to the weight of goods, in the same ratio as they were proposed for the Liverpool and Manchester railway, and also to the work that the ten-horse engine, proposed by him and Mr. Walker, would be capable of doing.

TABLE.

ENGINES.	RAIL ROADS.	IN SUMMER.												IN WINTER.											
		At 5 Miles per Hour.				At 8 Miles per Hour.				At 10 Miles per Hour.				At 5 Miles per Hour.				At 8 Miles per Hour.				At 10 Miles per Hour.			
		Goods.	Carriages.	Engine and Tender.	Gross Weight.	Goods.	Carriages.	Engine and Tender.	Gross Weight.	Goods.	Carriages.	Engine and Tender.	Gross Weight.	Goods.	Carriages.	Engine and Tender.	Gross Weight.	Goods.	Carriages.	Engine and Tender.	Gross Weight.	Goods.	Carriages.	Engine and Tender.	Gross Weight.
		Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Engine on six 4 feet wheels, Hackworth. ..	Stockton & Darlington.	47¾	23¾	15	86½	26	18	15	54	18¾	9½	15	43¼	40¾	20¼	15	76	21¾	10¾	15	47¾	15¼	7¾	15	38
Engine on four 4 feet wheels ...	Stockton & Darlington.	34⅗	17⅓	12	64	18⅗	9⅗	12	40	13⅓	6⅗	12	32	28¾	14½	12	55¼	15	7½	12	34½	10$\frac{4}{10}$	5$\frac{3}{10}$	12	27$\frac{6}{10}$
Engine on four 4 feet 2 inch wheels ...	Killingworth Colliery	38	19	10½	67½	21	10½	10½	42	15½	7¾	10½	33¾	31¼	15¾	10½	57½	17	8½	10½	36	12	6½	10½	28¾
Engine on four 3 feet wheels ...	Hetton Colliery	24¼	12	10½	46¾	12½	6¼	10½	29¼	8⅗	4⅓	10½	23½	19¾	9¾	10½	40	9¾	4¾	10½	25	6¼	3¼	10½	20
Engine on 4 wheels, rack rail ..	Middleton Colliery, near Leeds.	22¼	11	6¼	39½	12¼	6¼	6¼	24¾	9	4½	6¼	19¾	19¼	9½	6¼	35	10¼	5¼	6¼	21¾	7½	3¾	6¼	17½

I shall not attempt any minute description of railroads and locomotive engines to be used thereon, but refer my readers to the second edition of a treatise on railroads by Mr. Wood. The present work is more immediately intended to relate to steam-carriages without railroads, although a short description of boilers and locomotive engines used upon railways will appear hereafter. The value of railway conveyance will be seen in subsequent chapters.

It is certainly very difficult to account for the long delay in the adaptation of a steam-carriage to a common turnpike road. Engineers seem to have been shut up to the belief that it was impossible. Their very limited knowledge of the nature of a locomotive engine and its operation, precluded speculation as to this more extensive application; in much the same way as the limited knowledge of steam-boats in 1814 retarded, for so long a time, steam navigation on the ocean.

On a railway, the slight adhesion of the surface of the wheels to the rail was inadequate to propel the locomotive engine up any considerable ascent. This difficulty seems to have engendered the notion,—a notion scarcely yet removed, though proved to be absurd by a host of facts,—that a steam-carriage could never ascend a hill of even moderate acclivity upon the common road.

We cannot but connect this difficulty with an anecdote which, we doubt not, is familiar to many of our readers, and which, without wishing to appear illnatured, is so descriptive of the conduct of several scientific men with whom steam-carriage projectors have to deal, and so apt to our purpose, that we cannot pass it by.

A laughter-loving monarch once proposed to the philosophers, projectors, wise men, and civil engineers of his court, with a gravity becoming the importance and intricacy of the matter, the following problem:—"Take a globe of any given dimensions, fill it with water, and then put a gold fish into it: how does it come to pass, that by doing so you neither cause the water to overflow, nor increase the specific gravity of the globe and its contents?" Here was a puzzler to be sure! The whole conclave were thrown upon their beam-ends, and to resolve the difficulty became a subject of almost national concern. Then there was such a laying of heads together! and learned descantings, philosophic disputations, and theories, were broached in support of it—all of them most weighty, ingenious, and deep. Each party sported

> ———" Speculations wild,
> And visionary theories absurd,
> Prodigiously, deliriously absurd;
> Compared with which, the most erroneous flight
> That poet ever took when warm with wine,
> Was moderate conjecturing."

Each opposing stoutly the opinion of the other. At length an individual of the number, more sceptical and less credulous than his associates, suggested the propriety of putting the matter to the proof. The bubble burst, and the fact, encumbered as it was with a load of theoretical supports, showed the gravity to be, *plus* the gold fish. These philosophers were nonplussed, and the king had his laugh; but the result should have proved a warning to all sapient fraternities to the end of time. It finds, however, a curious and ludicrous application in the present day; the *non-possibility of steam-carriages ascending a hill* is still the *fish in the bottle* with many of the wise men. They have met often, and discussed long, and talked learnedly, and descanted philosophically, and endeavoured to make out the *non-possibility* of it, by all manner of arguments and means. But the fact outlives their reasonings, and the possibility of the thing proved *experimentally*, rests upon a plain practically demonstrated basis.

When inventors turned their attention to common roads, every one of them seems to have resolved that the boilers then in use on a railway could not be adopted on such roads as then were common. Therefore, light boilers, or boilers holding but a small quantity of water, were resorted to as the first requisite. Light boilers were now invented in abundance. Scheme upon scheme, and patent after patent, in rapid succession, appeared canvassing for public approbation. Out of the abundance, three or four only were happy hits; and these few have been gradually working their way into general use.

Mr. Julius Griffith, in 1821, had a steam-carriage constructed by Messrs. Bramah and Sons. It was intended to work on a good turnpike road. Many experiments were made with it in Messrs. Bramahs' yard, where it was to be seen for three or four years afterwards. A drawing of the arrangement of pipes in this boiler will be found on Plate X. Fig. 3. The engines, pumps, and connections, were all in the best style of mechanical execution; and had Mr. Griffith's boiler been of such a kind as to generate regularly the required quantity of steam, a perfect steam-carriage must have been the consequence.

This leads me to a remark, applicable in almost all cases, though perhaps not in this,—that much money has been expended, and an age of time lost, on the one hand, by steam-carriage projectors (for common roads) adhering too closely to their own views, and rejecting counsel; and from the prejudice of experienced engineers on the other. When engineers of known ingenuity and experience are applied to, their advice should have every weight with the projector.

In 1822, the late Mr. David Gordon, the inventor of the portable gas-lamp and the pneumatic apparatus required in the compression of air, took out a patent for improvements in wheel-carriages, part of which he specified to be propelled or drawn by elementary power.

Fig: 8.

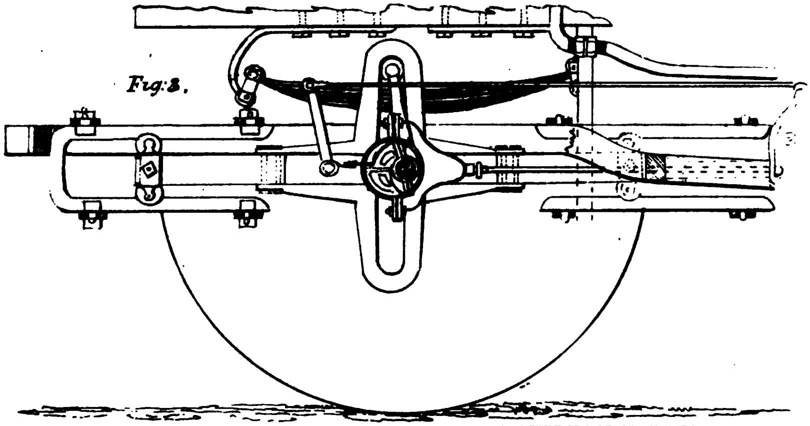


Fig. 2

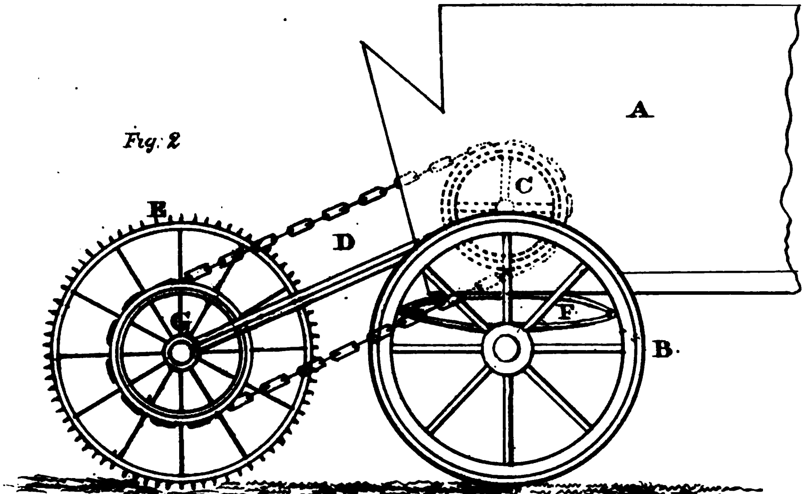


Fig 3.

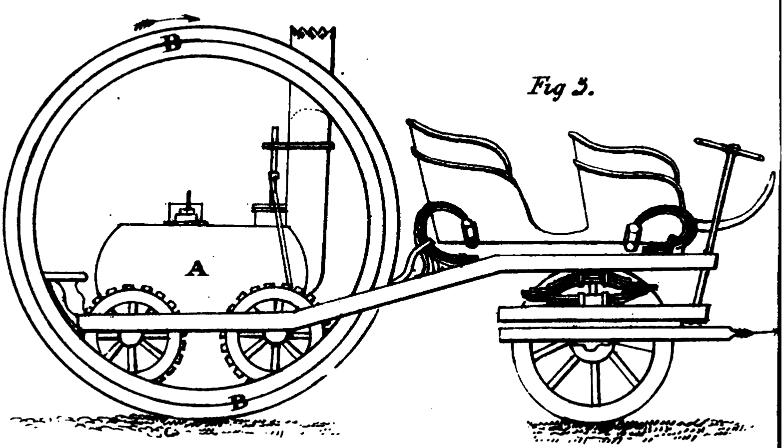


Plate V. fig. 1. represents a side elevation of this machine. A, the high-pressure steam-engine, made after the pattern of Mr. Trevethick's, and having the wheels made with teeth, worked into a rack in the interior of BB, the large rolling drum, about nine feet in diameter, and five feet from end to end. In the inside of this, there was an iron rack, on which the toothed wheels of A worked. By this arrangement the steam-engine, urged forward by its steam, climbed up the interior of the drum, as a turnspit dog or squirrel would do in its daily labours; and the large drum, rolling onward, impelled the carriage.

Mr. Samuel Moyle, at a subsequent date, used a large drum of this kind with great advantage for the transport of heavy goods over a swamp in South America. Having a quantity of plate-iron, which was too heavy to carry over otherwise, he rivetted the plates together into the shape of a large cylinder, and carried other heavy goods in the inside of it. As the party advanced, this huge machine rolled with them. Afterwards the rivets were cut off, and the iron plates, arrived at their destination, were put to other use.

In 1824, Mr. David Gordon took out another patent for an arrangement of machinery, by which an action similar to horses' feet could be obtained. This was effected by six hollow iron legs, at the lower extremity of each of which there were feet to push upon the ground. These legs were connected by brasses, straps, and keys, to the outer journals of the eight-throw crank, C C, &c. Plate VI. fig. 1. This crank was propelled by the pair of steam-engines, *d d*, fig. 2, on the same shaft. This crank pushed out the legs backwards, and the carriage run forward. The legs were thus projected in succession: 2 following 1, and 3 following 2 (see fig. 2); then 4, 5, and 6, follow in the same course, each pushing the ground. By following this motion of the feet, it will be found necessary to use lifting-rods. These rods were hollow, and had a small solid rod in their interior, which was pressed out by a spiral spring in the hollow rod; so that these connecting-rods (the lifting apparatus), were lengthened when the feet got into a hollow, and shortened if the feet got on a stone or other little eminence betwixt the tracks of the wheels.

Figure 1 exhibits three of the driving and three of the lifting-cranks, with their corresponding three propellers.

After attempting to make a light boiler (as described in the chapter on boilers), which he felt to be a desideratum, Mr. Gordon applied to Mr. Gurney, and obtained one of his boilers hereafter described. This boiler was situated in the hind part of the body.

The whole was supported by three wheels, one in front and two behind; each wheel being supported on both the outer and inner side, and having its own axle. There was thus no axletree extending from side to side, and the well, or lower part of the body, was made of a large size, so as to keep the centre of gravity near the ground.

In my evidence before the Committee of the House of Commons (in 1831), I stated that Mr. Gurney's progress in 1826 and 1827, showed clearly that this arrangement was not necessary in every case, but that one of the wheels of the carriage, when attached to the steam-engine, had a sufficient hold of the ground to give progressing motion to the carriage, without using propellers; and the introduction of that invention has subsequently been given up by me in consequence.

Both the plans plate V, fig. 1, and plate VI, figs. 1 and 2, have been given up. Mr. Gurney had made such great advances, that it would have been throwing away money to have gone on further with them. I had found that the propelling feet, shown in the middle of the engine, do more injury to the roads than the propelling wheels.

Plate 6.

Fig: 1.

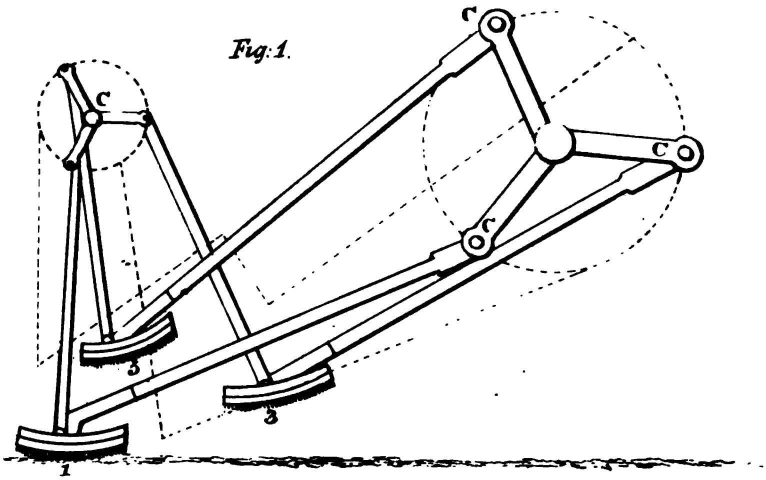
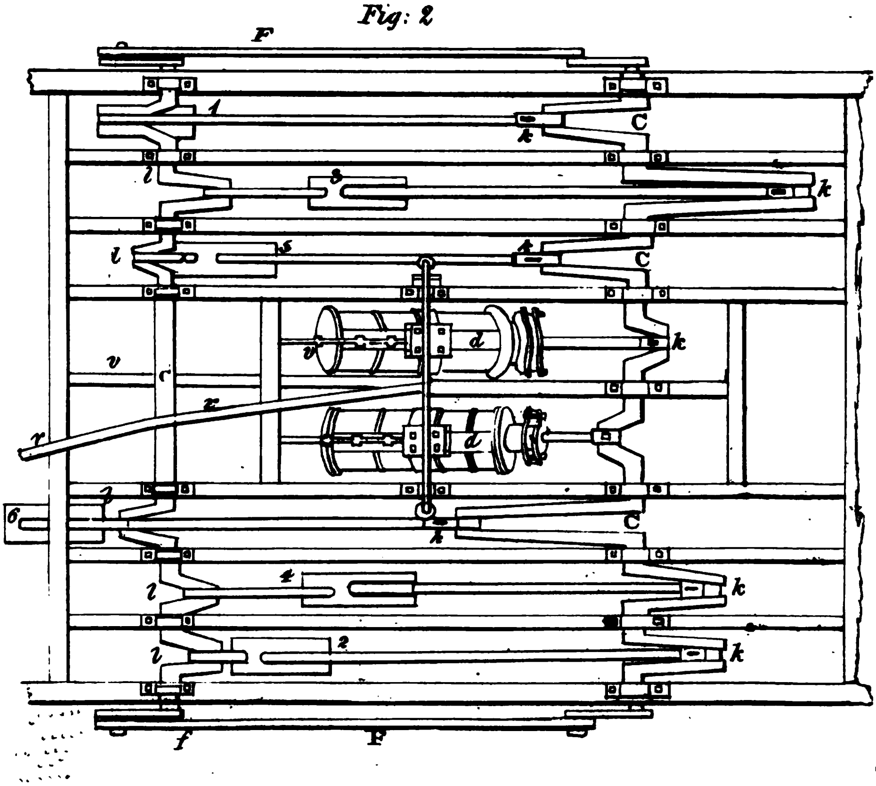


Fig: 2



Still, there are many situations and seasons in which a steam-carriage using its power in this manner may be highly useful. A road covered with ice, a sandy soil, or a very soft soil, such as a ploughed field, when steam-power is applied to the plough or harrow. Nor is this latter case so remote. When steam-power is once established on the roads, it will not be long before it reach the fields.

In 1826, Mr. Samuel Brown applied his gas-vacuum engine (see page 29) to a carriage, and ascended Shooter's-hill to the satisfaction of numerous spectators. The great expense, however, which attended the working of a gas-vacuum engine, prevented its adoption.

In November, 1825, Messrs. John and Samuel Seaward, of the City Canal Iron-works, obtained a patent, under which their claim was for "the propelling locomotive engines, vehicles, and other carriages, by means of a wheel or wheels connected either by a swinging frame or frames to the crank-shaft of a steam-engine, or other moving power, or working in circular grooves, so that it, or they may rise or fall to accommodate themselves to the roughness or unevenness of the ground, but supporting no part of the weight of the said engine, such weight being entirely supported by separate wheels."

The locomotive engine, A, plate V, fig. 2, was placed on two pair of wheels, B; C is the crank-shaft of a steam-engine within the body of the machine; to the shaft, C, is attached the swinging-frame, D, with a propeller, E, turning on its axis, G, at the vibrating end of the swinging-frame. The steam-engine was upon the springs, F, so that the machine might travel on rough roads.

In 1829, Sir James Anderson and Mr. James constructed a steam-carriage under the patents obtained by the latter gentleman in 1824 and 1825. The striking feature of this invention was the boiler, and the high pressure (three hundred pounds per square inch) these gentlemen are said to have worked with.

The cylinders were four in number, and placed horizontally between the hind wheels. The speed of the carriage was at the rate of nearly fifteen miles in the hour. But the structure of the boiler, as described hereafter, leads me to doubt whether the steam could be regularly kept up, and, consequently, to doubt if the carriage could ever travel fifteen miles *in the hour*.

Messrs. Hill and Burstall obtained a patent in August, 1826, for improvements in the machinery for propelling locomotive carriages. One constructed on their patent was exhibited in Leith and in Edinburgh, and also in front of Bethlehem Hospital, London, in 1827; at which latter place I saw and examined it in operation. This carriage, however, was soon abandoned; and therefore readers are referred to the Repertory of Patent Inventions for February, 1828, where an account of it will be found.

Inventors seemed now to have received a new impulse. Their multifarious plans, good and bad, burst upon us in quick succession; some to make a noise and bustle for a time, and some merely to twinkle from their obscurity, and vanish without leaving even a remembrance behind.

Perhaps many valuable inventions have not been made public. At the same time there are many inventions in locomotion, which, at this early stage of history, are so little known to us, that we cannot give an account of them.

Mr. Goldsworthy Gurney, in 1825, produced a steam-carriage; and his improvements upon it led to the successful introduction, by Lieut.-Col. Sir Charles Dance, of steam-carriages on turnpike-roads, as an established and regular conveyance for the public betwixt Gloucester and Cheltenham, in February, 1831, until certain landlords and horse-jockeys, by an opposition which, it has been well said, would have disgraced a nation many hundred years behind England in civilisation, compelled Sir Charles to abandon the road.

Mr. Gurney obtained a patent for a locomotive carriage in 1825, which is described in the Repertory of Arts in the following manner:—

"In this apparatus, the carriage has two straight perches parallel to each other, a small distance asunder, which have grooves or hollow channels made at their lower side, for the greater part of their length; in these channels oblong blocks are placed, furnished with vertical and horizontal anti-friction rollers, to facilitate their motion forwards and backwards, and from their sides, slips project that run in grooves made at the sides of the channels, and which serve to prevent the blocks from falling out, if the carriage should be raised; from the bottom of these moveable blocks, legs or crutches of metal descend to the ground, by which the carriage is impelled; these legs have a flexure at their tops, towards the head of the carriage, and another at their heels, in the contrary direction, to which a curved shoeing is fastened, to keep them from being worn; they are attached to the blocks merely by a vertical bolt that passes through the front of the upper flexure a small distance, where it is terminated by a nut and screw; between which nut and the flexure, a spiral spring is placed, which, by its yielding, enables the heel to pass better over small obstacles, and again draws the head up to its proper position: these legs may be turned round on the bolts at their heads, when it is required to move the carriage in a reversed direction.

"The carriage is impelled by these legs being drawn alternately forward, and pressed backwards by a steam-engine, that acts on the blocks in the following manner:

the main cylinder of the engine is placed horizontally, and the head of its piston-rod is sustained by a piece of metal, placed in a similar position, on which a vertical anti-friction roller, attached to it, runs; one end of which piece rests on the bed of the cylinder, while its other extremity is fastened to the back of an upright bar, that ascends from the front of the carriage (to which it is also connected at each side by an oblique brace) to some distance above the level of the cylinder, bending forward at the same time; and from whose head two movable levers descend to a line with the blocks of the impellers; two other levers, which are jointed to the front of the carriage, midway between the cylinder and the upright bar, on the contrary, ascend, a little way above the top of the cylinder, and are there connected to the descending levers by horizontal rods, which are jointed to them at their different extremities; the lower ends of the descending levers are, in their turn, connected by similar horizontal rods to the impelling blocks, so that when the first, or ascending levers, are moved back, and forwards, this motion will be communicated to the blocks by the other levers, and the horizontal rods mentioned; and these two ascending levers are made to have this motion by one of them being connected by a joint with the head of the piston-rod, from which chains pass round horizontal pulleys (that lay in mortices made in the piece of metal which the anti-friction roller of the piston-rod runs on) to the other ascending lever; so that, when the piston-rod draws the one back the other is drawn forward by the chain, and the contrary when the other impels it forwards. These two pairs of levers, thus placed, permit the speed of the carriage to be increased or diminished, by shifting the horizontal rods that connect them to higher or lower positions on them, for which purpose several holes are bored through them, at regular intervals."

In his first experiment he ascended Windmill-hill, near Kilburn, but being then of the prevailing opinion that the friction of the wheel was not sufficient to impel the carriage up acclivities, he used the legs, or propellers. This application of levers was inconvenient and heavy, and after much thought and experiment, a combination of these levers and the wheels was resorted to. It was so arranged, that when the wheels should slip, the levers should come into action. A trip by steam, betwixt London and Edgeware (nine miles and a half distant from Mr. Gurney's factory), was effected by this arrangement. The levers were subsequently entirely abandoned, the wheel being found not only to be sufficient for impelling the carriage, but also to allow considerable free traction.

About this time Mr. Gurney attempted to work without a crank, by adopting an arrangement sketched on plate V, fig. 3.

On the 15th September, 1830, the Liverpool and Manchester railway was opened for public traffic, with eight of Messrs. Stevenson and Co.'s locomotive-engines; the Northumbrian led the procession on that occasion. Plate VII. figs. 1 and 2, represent this engine; A, the boiler; B, the situation of the fire; from whence a number of small tubes through the water convey the heat to the chimney, C. D D, the cylinders of the engines; E E, the valve motion; F, one of the piston-rods. A tube from the waste steam-pipe to the bottom of the furnace enables the engineer, by turning a cock, to pass the superfluous steam through the fire in aid of the combustion. The boilers of all of Mr. Stevenson's engines are not tubular, but have tubular flues; that is to say "a series of straight tubes of equal diameters enclosed in one general casing, and immersed in water." This engine has 150 of these tubular flues, and weighs 6 tons 3 cwt.

"On the 23rd of February, 1831, Mr. Robert Stephenson stated to the Society of Civil Engineers, that the Northumbrian locomotive engine drew 50 tons up the inclined plane at Rainhill, at the average rate of 7½ miles per hour: pressure of steam was 50 lbs. on the square inch. The inclination of the rails at Rainhill is 1 in 96.

On the 23rd November, 1830, the distance betwixt Manchester and Liverpool was travelled by one of Mr. Stevenson's engines, the Planet, in sixty minutes! of which two minutes were taken up in oiling and examining the machinery midway. No train of carriages was attached to the engine in this case, and only three persons were upon the engine. These engines of Messrs. Stevenson and Co. produced the draught by the rapid discharge of a jet of steam up the chimney.

I find recorded in the Institution of Engineers, that the Samson engine (Stevenson and Co.'s) on 25th February, 1831, started from Liverpool with thirty waggons, carrying 82½ tons of oats in twenty-three waggons; 24¾ tons of merchandise, and 1 ton weight of passengers (fifteen persons) in seven waggons 108¼ tons. To which add 42¾ tons for the tares of the waggons, in all 151 tons. The engine was 8½ tons weight; the tender with coke and water 5 tons. With this enormous load, 164½ tons, the speed of the engine averaged twenty miles an hour on the level; but when the train came to the inclined plane, the Samson only drew 62 tons, but with itself and tender 72½ tons. The inclination of the rails was 1 in 96. The two cylinders of this engine are fourteen inches diameter, and the stroke sixteen inches. The wheels are 4½ feet diameter, and are all four attached together. Effective pressure per square inch of the boiler, thirty-five lbs.

In October, 1829, the *Rocket*, *Novelty*, and *Sans Pareil*, were started on a level part of the Liverpool and Manchester railway for a premium of £500.

	Tons.	Cwt.	Qrs.	Lbs.	
Mr. Geo. Stevenson's *Rocket* weighed	4	5	—	—	—Full speed 30 miles in 2 h. 14 m. 8 s. equal to $13\frac{4}{10}$ per hour; back 30 miles in 2 h. 6 m. 9 s. equal to $14\frac{2}{10}$ per hour.
Tender, with water and coke,....	3	4	—	2	
Two carriages loaded....	9	10	3	26	
	17	—	—	—	

	Tons.	Cwt.	Qrs.	Lbs.	
Mr. Hackworth's *Sans Pareil*—weight of engine....................	4	15	2	—	—Full speed $10\frac{1}{2}$ miles in 50 m. 49 s., equal to $12\frac{4}{10}$ per hour; back 12 miles in 40 m. 27 s., equal to $15\frac{5}{10}$ per hour.
Tender, with water and fuel......	3	6	3	—	
Three carriages..................	10	19	3	—	
	19	2	—	—	

	Tons.	Cwt.	Qrs.	Lbs.	
Messrs. Braithwaite and Erricsson's *Novelty*—weight of engine with water in the boiler	3	1	—	—	—Total time, 22 m. 57 s., and distance run $4\frac{1}{2}$ miles
Tank, water, and fuel,..........	—	16	—	14	
Two carriages.................	6	17	—	—	
	10	14	—	14	

"On the 19th of April, 1831, Mr. Locke stated to the Institution of Civil Engineers, that 'The Samson' drew up the inclined plane at Rainhill about $44\frac{1}{2}$ tons gross of goods and waggons, at the rate of about 8 miles an hour.

"He also stated, that a new engine, 'The Jupiter,' from the 4th of March to 6th of April, drew 226 waggons (only 10 of which were empty) and 847 coaches, a total distance of 3,426 miles. In one fortnight she made 50 journeys, equal to 1,500 miles. Diameter of cylinder, 11 inches; length of stroke, 16 inches; diameter of the wheels, 5 feet. Value of such an engine, £700."

In no part of the world has a good communication from place to place been more sought after than in the United States of America; yet there steam-carriages have not kept pace with steam-boats. Many railways are, however, in contemplation, and a rail-road of unexampled extent is now in the course of formation from Baltimore, across the Alleghany Mountains, to the Ohio. A locomotive railway carriage was designed by Mr. Howard for this railway; for an account of which the Mechanics' Magazine, No. 328, may be referred to.

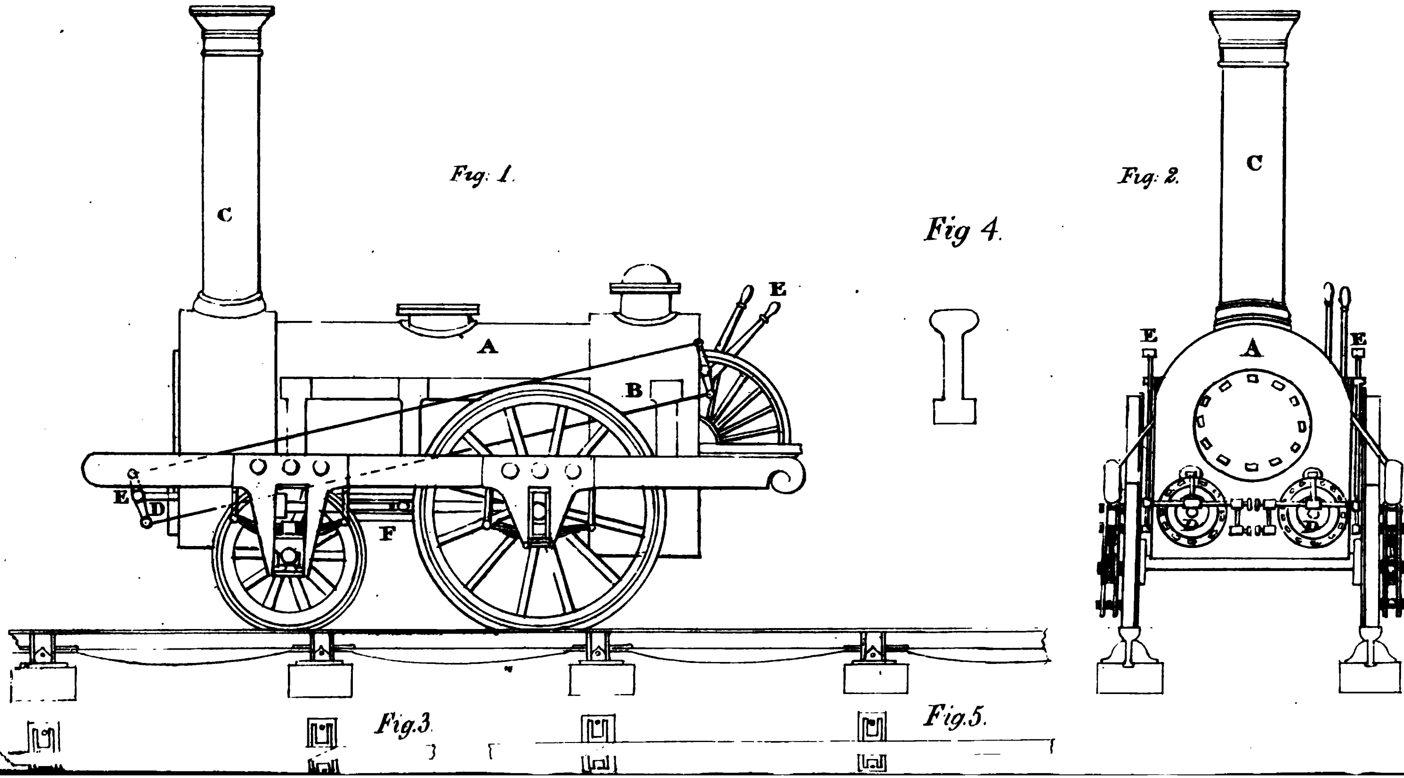
The first desideratum which Mr. Howard made it his study to accomplish in this engine, has been to render the axletrees capable of adapting themselves to the curve of the road, so that a perpendicular plane drawn through the centre of the axle may be normal to the curve.

The usual beam, fastened by jaws to the axles, is divided in the centre, and a tooth and socket permit one end to play in the other. This contrivance obliges the hind wheels to follow in the track of the fore ones. Besides this, there is a beam extending from one axle to the other, and traversing on the centre of each round a strong bolt. To this beam the boiler, with the cylinders, are attached. The boiler, indeed, may be made to answer the purpose of this beam.

The next point to which Mr. Howard has directed his attention, is the means of making the outer wheels go faster than the inner ones.

In the beginning of the year 1831, the Directors of the Monkland and Kirkintilloch Railway (near Glasgow) directed their engineer to make out a plan and specification of two locomotive engines, able to drag sixty tons, gross weight, at the rate of four or five miles an hour. This was done accordingly, and the engines were contracted for by Messrs. Murdoch and Aitken, engineers, Hill Street, Glasgow, who brought the first upon the railway on the 10th day of May, and the second upon the 10th of September, the same year. Both engines travelled several miles upon the railway the first day they were brought out of the yard at Glasgow, and have since, during a course of eighteen months' trial, proved themselves the most efficient engines of the kind ever made in the kingdom, being capable of taking ten tons more on a level railway than any

Plate 7.



engine yet made of the same size of cylinder, with a pressure of fifty pounds to the square inch upon the boiler.

The line of railway on which these engines daily travel, is one of the very worst description, for the effectual working of such engines, being eight miles and a half in length, with numerous abrupt curves and descents. The descents are one in 50, one in 116, one in 120, &c; the curves are of a radius of 344 feet, the arch 335 feet, radius 400 feet, arch 650 feet, radius 700 feet, arch 545 feet, &c. The descents being in favour of the load, the bringing up the empty waggon is considered the heaviest work, yet one of these engines has frequently returned from Kirkintilloch, where the railway ends, with fifty empty waggons, in the ordinary course of trade, the weight of which being about sixty tons; but, when loaded, they carry a gross weight of about 200 tons. The daily load of each engine is from twenty to fifty loaded waggons, according to the circumstances and trade occurring on the road.

One of the great improvements on these engines is, the metallic packing of the pistons, which are the first of the kind ever used, and of such a description that the two engines have not cost one shilling in eighteen months for packing, and use neither grease nor any other unctuous substance whatever for the cylinders, since their commencement; another, and perhaps the greatest advantage of these pistons is the economy of labour, the reduction of friction, and the saving of fuel thereby effected, the area of the fire-place being just four feet, or one-half of the size of that in the Liverpool engines. These pistons are each formed of two iron rings in three segments; a wedge between each segment is pressed by a spiral spring.

In the Report by the Directors of the Monkland and Kirkintilloch Railway to the proprietors, at their general meeting on the 1st of February, 1832, these engines are noticed in the following manner:—"Your Committee have, as mentioned in last year's Report, built two locomotive engines, which have been in employment on the railway for nearly six months, and the whole of the trade from the collieries to Kirkintilloch is now drawn by these machines. The committee, after much consideration, devolved the whole form and plan of these engines to Mr. Dodds, the superintendent. It was strongly urged by some of the proprietors that these engines should be got from England, and that the improvements of the engines adopted on the Liverpool railway should be introduced in constructing those for the company. On inquiry, however, no certain data could be obtained whereby to calculate what would be the expense of maintaining in repair such improved engines; and it was also ascertained that they were very liable to be deranged when working at the high speeds for which they are calculated. For these reasons, the committee devolved on Mr. Dodds the entire responsibility of the planning of the engine, and the result of their confidence has been in the highest degree satisfactory. Mr. Dodds, in his plan and specification, adopted none of the recent improvements, except that of the copper tubes, suggested by Mr. Beath, giving however a great additional strength to these tubes. The contract for making the engines was taken by Messrs. Murdoch and Aitken, Hill Street, Glasgow, and the committee are satisfied with their performance, except as to the time taken by them in furnishing the second engine. This is no small praise, considering they were the first locomotive engines constructed in Glasgow. The excellence of Mr. Dodd's plan and specification, so far as several months' trial can be considered a proof, is most satisfactory, as the engines have never been one day off work, except on two occasions, when injured by the malice or carelessness of certain waggoners on the road. On the other hand, the engines procured from England, by an adjoining railway company (the Garnkirk), have been repeatedly taken off the road, on account of needing repairs, &c."

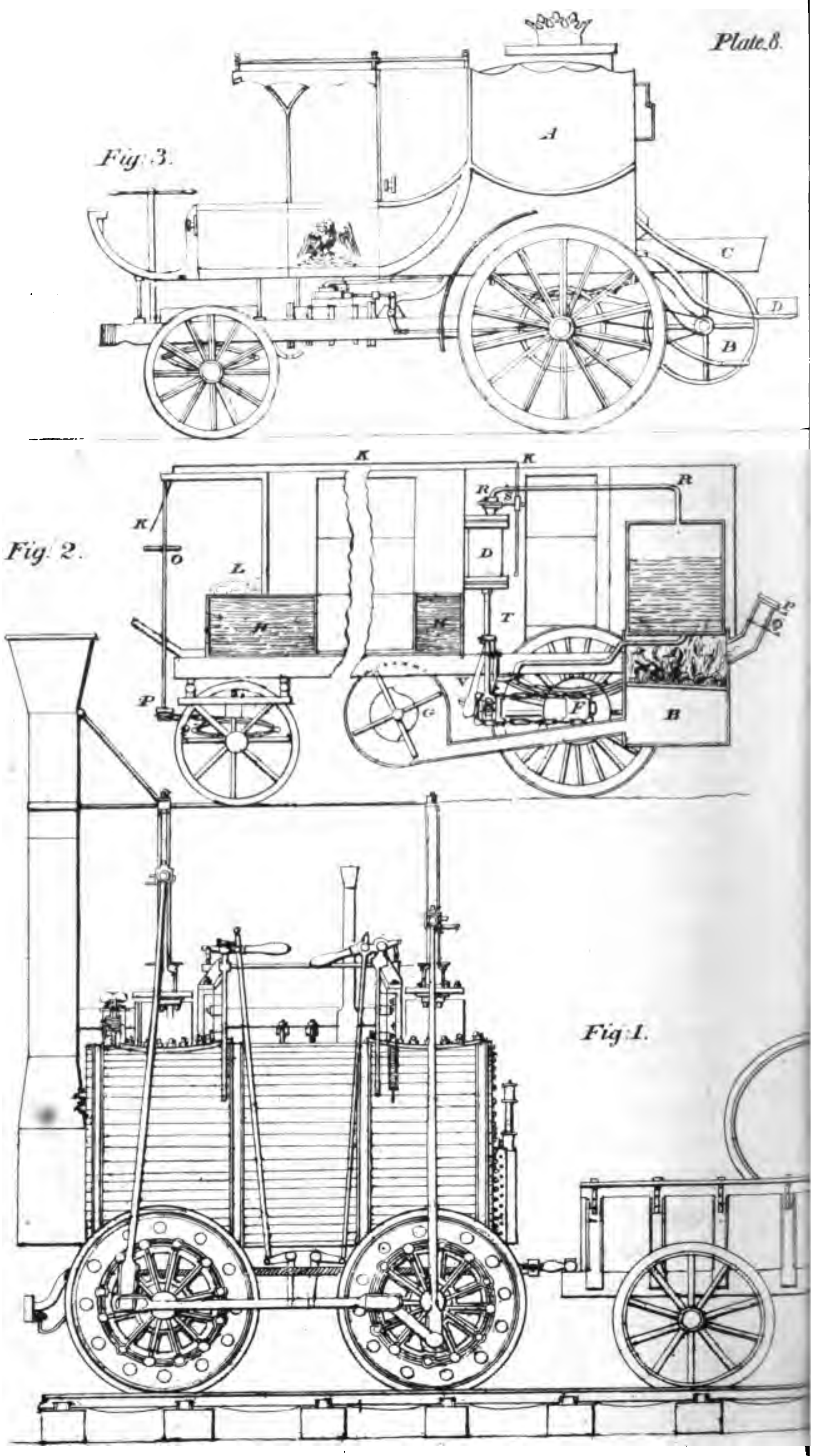
Since the date of this Report, these engines have done all the trade to Kirkintilloch and other places, for another year, and have not been off one day, or employed a single horse to assist them. These are facts, and the best criterion whereby to judge of their real performance, or to make comparison between them and other railway locomotive engines.

The connecting-rod between the two wheels has a ball and socket-joint at each end, making universal joints. The wheels have a play upon the axle of about one inch, to allow for turning in the above curve. The cylinders are $10\frac{1}{2}$ inches diameter each, and the stroke is 2 feet; pressure of steam, 50lbs. The average speed of these locomotive engines is now 6 miles per hour. The regulation is 5 miles per hour; but they sometimes even double the regulated speed. On plate VIII. fig. 1. a view of this locomotive engine is given, with the tender attached.

In October, 1827, Mr. Gurney obtained another patent for improvements in locomotive engines, and in the apparatus connected therewith. Under this patent he worked with a steam-carriage, resembling, in external appearance, the common stage-coach, the boiler being situated in the hind boot. In the fore boot a blower, like the revolving fans of a winnowing machine, moved round horizontally in a close box, from which a tube conveyed the blast to the close ash-pit of the fire-place. The engines acted upon the cranks on the hind axle. "The hind wheels had sockets, or boxes in their centres, like common wheels, so that either of them might be made to run loose on the axle when required; and they were fastened to the axle so as to turn round with it, at other times, by means of a round plate fitted on a hexagonal part at each end of the axle; and a similar plate being fastened to the nave of each wheel, close to the former, screw-bolts passed between the two plates, and, secured with nuts, gave the desired connexion, which could again be withdrawn by removing the bolts."

Although Mr. Gurney's boiler, described in our chapter upon boilers, is perhaps the distinguishing feature of that gentleman's invention, there are other important arrangements worthy of minute notice. The arrangement of his machinery is as follows:—On Plate IX. fig. 1 is an elevation of part of the carriage without the boiler, and fig. 2 is a plan of the same carriage. Similar letters are used at the same parts of each figure, and a straight line drawn vertically through any part of either figure, will be found to pass the corresponding part on the other figure. The steam generated in the boiler, which is placed in the hind boot of the carriage, in the position, A A, passes along the pipe, B, past the throttle-cock, C, and enters the valve slide at D. The piston-rods, E and F, are connected by double rods or bars to the cranks, G G, which being on the same shaft are moved simultaneously in the direction of the arrow (upon fig. 1). Upon this crank shaft, which serves as the hind axletree of the carriage, one or other (and sometimes both) of the hind wheels, H H, is made fast in such manner, that as the crank shaft is forced round, the wheel fixed thereon is forced round at the same time; and, as the rubbing surface betwixt the wheel, H, and the ground is sufficient to prevent the wheel from slipping on the ground, the wheel pulls or pushes the carriage onward, in whichever direction it is turned by the engine. Upon the crank shaft will be seen the eccentrics, J K, which revolving in smaller circles, and at different angles with their respective cranks, produce that motion in the valve slides which is necessary for admitting the steam at one side of each piston from the pipe, D, and for allowing it to blow off from the other side of each piston by the eduction pipe, L, (as described on pages 19 and 20.)

Plate. 8.



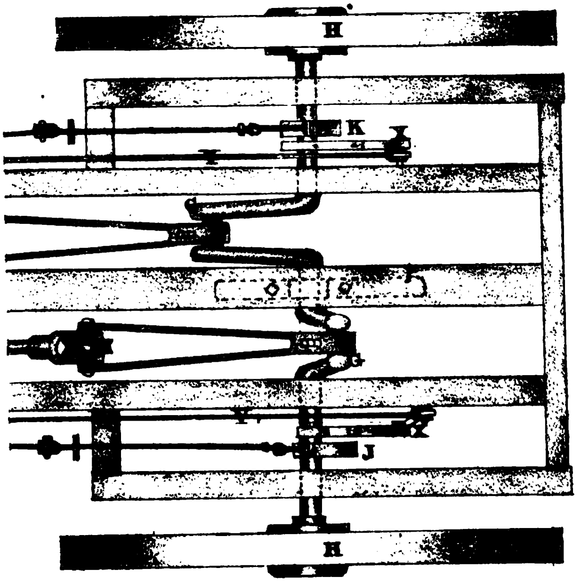
At this period Mr. Gurney allowed the waste steam to blow into the cold water tank, M. From this tank the supply of water necessary to replace that evaporated in a state of steam from the boiler, was pumped into the boiler by means of a force pump.

The guide's seat was placed above the position of the letter C. By raising or depressing the handle of C, the throttle-cock is more or less opened or shut, and consequently a greater or less supply of steam is admitted through the valve slides (at D) to the pistons; and thus the engines are driven faster or slower, or are started or stopped. By pulling up the lever, N, he can reverse the action of the engines, and so cause the carriage to run backwards: the steam being thrown from one side of the piston to the other. There are many arrangements by which a reverse motion can be obtained, and which will at once suggest themselves to engineers and others acquainted with mechanical movements.

In this carriage, Mr. Gurney employed a pole, R, under the extreme end of which there were a pair of small guide wheels, attached by a perch-bolt to the pole. The top of the perch-bolt was fitted with a square iron loop, S, which, again, had the steersman's handle or lever, T V, fastened upon it. In this manner the guide, who was seated above C, could turn the pole in any direction, and the pole being turned, the fore-wheels of the carriage would be guided straight, or to the one side or other, and, if necessary, completely locked round. W was a strong brace for strengthening the fore-part of the carriage. X is formed of a plate of steel, and as the eccentric, J, revolves, X will be seen to move the whole connexion of expansion-rod, Y, and expansion lever and cock at Z. At one-half or two-thirds of the stroke the steam was shut suddenly off from the boiler, and that steam already in the cylinder of the engine expanded itself, and completed the stroke. A saving was thus produced, but care must be taken, when working by expansion, that more apparatus is not required than the advantage sought will warrant.

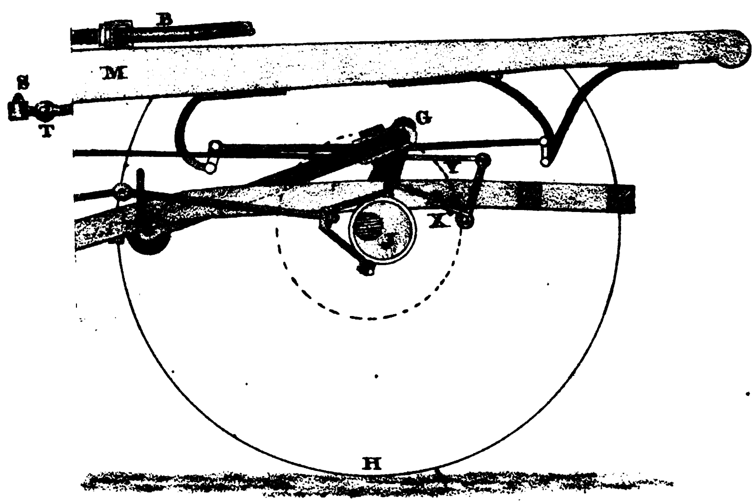
In all of his last coaches, the patentee has discontinued a blast for urging the fire, and has used the waste steam to occasion a draught. This is effected by blowing the waste steam by several small jets upwards into the lower part of the chimney. The increase or decrease of draught is regulated by the size of the aperture through which it is ejected. A very perfect draught is thus obtained, and the fire can be enlivened or damped according to the required speed of the engine. With a boiler containing so small a quantity of water, and so large a proportion of heating surface, the facility of lessening or increasing the heat, and consequently the power of the steam, is very great. And this facility is highly important for economising fuel, and for the quick and certain management of the steam-carriage on hilly or crowded roads.

In February, 1831, Mr. Gurney having completed three steam-carriages for Sir Charles Dance, that gentleman commenced running one regularly on the road betwixt Gloucester and Cheltenham, and continued so to do constantly and successfully for four months, until he (disgusted with the opposition) withdrew his coaches. So strongly did the opposition press upon steam-carriages, that Mr. Gurney found it necessary to petition the House of Commons. Several bills had hastily been passed through Parliament, laying prohibitory tolls on steam-carriages, in some cases amounting even to 2*l.* for each time the steamer should pass. Such bills may have originated with agriculturists, who had not weighed the advantages; or



A A

A A



Printe

Drawn on Stone by Alex. Gordon

may have originated in a notion that a "steam-carriage was a steam-boat on wheels *," or partly in the habits of some country gentlemen, who love no change. Be that as it may, an investigation took place, which has caused this science to shine forth with increased lustre.

Mr. Goldsworthy Gurney said, in his evidence before the Committee of the House of Commons in the year 1831:—

"The first road I commenced upon with my steam-carriage was Edgeware, then Stanmore; I ran there for a short time only, principally experimentally; then to Barnet, to Edgeware, to Finchley, and other places. I also ran a carriage on my own account to Bath and back; that was only one journey—an experimental journey. Since that, they have been running as public stages, between Gloucester and Cheltenham.

"In the year 1825 it was a very prevalent opinion that the bite or friction of the power to the ground was not sufficient to propel the carriage along a common road, particularly up hill; it was thought that the wheel would turn round, and the carriage not proceed. With that view, the apparatus which I call feet or propellers were proposed to be used. I soon found by experience, in numerous experiments, that the propellers were rarely or never wanted; and I then applied the power immediately to the two hind wheels, through a crank, in the common mode of a steam-boat;—the propellers being also fixed, but travelling slower than the wheels, were brought into action if the wheels slipped, which it was thought would be the case in difficult situations. This carriage went up Highgate Hill, in 1826, and to Edgeware, also to Stanmore, and went up Stanmore Hill, and Brockley Hill,

* Such was a steam-carriage supposed to be, by an honourable member in parliament, before the date of the Reform Bill.

near Stanmore, and against all those hills the wheels never turned, and the legs never came into action. After these experiments, the legs or propellers were entirely removed, and from further experiment it was found, by a peculiar application of the steam (namely, by 'wiredrawing'), that the bite of one of the hind wheels was sufficient for all common purposes. If the steam was let on suddenly, the wheel would turn round, and the carriage not go forward; but when wiredrawn, one wheel was found sufficient. By this arrangement, also, the carriage was guided more accurately and more easily. The second wheel was applied by uniting it with the crank at any time, if one was found insufficient.

"One wheel was always attached to the axle, by the arm or carrier of the wheel (which is a part of the axle), and can be attached to the wheel at pleasure by a bolt, making the wheel also in that case part of the axle; this carriage ran to Barnet, and went up all the hills to Barnet, in 1827, with one wheel only attached to the axle, and was run for about eighteen months experimentally in the neighbourhood of London; from these experiments showing that one wheel was sufficient to propel the carriage, and the carriage being at the same time reduced two-thirds in weight, it was thought desirable to draw another carriage, instead of carrying on the same. This carriage went to Bath, and over all the hills between Cranford Bridge and Bath, and returned with only one wheel attached to the axle; the other carrier, by means of attachment, having broken in the first onset, and not having been repaired until after its return; the carriage was also injured slightly at Melksham, in consequence of a riot there; we waited about two days at Bath, to get this injury repaired, and returned from Melksham to Cranford Bridge in ten hours, a distance of eighty-four miles, including stoppages.

"My first carriage of a given power weighed four tons; this weight was severely felt in consequence of its effect on the roads. I thought it would injure the roads, and a toll might be imposed that would perhaps injure the economy of it: one weighed four tons; another weighed three tons, with the same power; another two tons, with the same power. They may be made to weigh only 35 cwt. The carriage which ran between Gloucester and Cheltenham weighs (by a letter from a magistrate, produced to the Committee) nearly three tons; it ought to weigh only 45 cwt.; if it weigh three tons, there is extra weight of which I know nothing. Those carriages at Gloucester were built principally under the superintendence of another person. I think it is possible to reduce the weight considerably as improvements go on.

"The stages into which the journeys are most conveniently divided are about seven miles. The fuel and water for such a stage will be in proportion to the size and power of the carriage. Three bushels and a half of coke would be taken to supply this distance of seven miles, and the first charge two bushels; the first charge always remaining, it decreases of course down to the first charge, and taking the mean it will be $3\frac{3}{4}$. The weight of water at present is about 10 gallons a mile which is consumed; that would be 70 gallons, a gallon weighing about 10 lbs., making 700 lbs., the mean of this will give the quantity. If the roads be good it does not take so much, we can do with almost half the quantity; if the roads be bad we must take the whole quantity, and the mean will be 350 lbs.

"The diameter of the wheel has generally been about five feet. The difference between the fore and hind wheels is about the proportion of an ordinary carriage. The power is attached to the hind wheels only. It is a matter of convenience and option whether the wheels should follow in the same track. I have built them with three wheels only, one wheel in front, and in some with six wheels; my present carriage has only four. The hind wheels of my present carriages follow in the same track with the fore wheels.

"I propose to have the propelling wheels of my new carriages about five feet diameter. I would observe, that by taking a wheel of five feet diameter off the axle, and putting on one of two feet six, the engine would be multiplied double in its power, and lose of course one half in speed; in some cases it may be desirable to do so if the carriages are used for general purposes; for speed and dragging of heavy weights alternately, larger or smaller wheels may be put to meet circumstances as they occur. The piston of the engine should not travel more than two miles and a half per hour; therefore we may multiply from this rate to any speed we please. The breadth of tire of the present wheel is two inches; but in late experiments a wide tire has been found more desirable than a narrow one, and we have increased it to about three inches and a half in width.

"My ordinary travelling engine is twelve nominal steam-engine horse-power; to work eight hours it takes the common stage-coach 32 horses; an engine propelling the same weight for eight hours should be considered a 32 horse-power, according to the rule laid down by engineers, but this is not true as to locomotive engines.

"I think about 10 cwt. of engine will do the work of a horse on the road; 35 cwt. will be about 3½ horses' work always; in each stage it will displace 3½ or 4 horses, and about 30 horses in the eight hours.

"The propelling carriage to draw a carriage containing 18 persons, would be about the weight of four horses;

the weight of the carriage drawn would be precisely that of a carriage drawn by horses, and I find the weight of a horse to average about 10 cwt.; therefore, taking four horses at 10 cwt., the four horses would be two tons, which is somewhere about the weight of my carriage; to do the same work, some horses weigh as much as 16 cwt., some considerably less than 10 cwt.

"I have seen my steam-carriage in a clay-pit, eight inches deep, propel itself along, having sunk through the upper surface of gravel in a yard. The power of the engine remains the same, but the application of it is doubled by the friction of two propelling wheels instead of only one.

"The effect, hold, or bite of the wheels in the ground is very different: if the state of the road be between half-wet and half-dry, it is more apt to slide; and in some instances, with a heavy weight attached, we are obliged to go with both wheels locked, when the same weight would have been taken by one wheel only, in very wet or dry weather.

"It is only in starting on a level or slight incline that this difficulty occurs; but up hills we have sometimes been obliged to attach both wheels, the bite only from the one wheel not being sufficient to propel a load behind it.

"The cause which occasions a crank to break is one which cannot be explained on common principles; it frequently happens, as in steam-boats; and very often in this carriage, when the power applied to it is not equal to its being broken, the accident occurs, and must be referred to a jar or percussion; the axles of my carriage are unusually large in consequence.

"I may state here, that I have had accidents of breaking the crank two or three times during my experiments; the last crank was broken in consequence of going through some rough stones laid as much as eighteen inches deep.

"The most frequent accident which will happen to my drawing-machines, I should say, would be the derangement of the pumps, in consequence of which the carriage would stop."

"During the experiments you have been making, have you frequently had your tubes burst?"—"Very often; but I conceive that I have remedied the probability of such occurrence: the first tubes we used were iron gas-tubes, which were not welded, but simply 'butted' together; the consequence was, that whenever any great pressure came upon them the seam opened; but from practice and experience, we found it necessary to wrap over, or over-lap the edges, and weld them from end to end; and now we are not subject to those accidents."

"The diameter of the tubes of the boiler are made from half an inch to two inches; the best size, I think, is an inch diameter. The pressure, per square inch, to which we prove them, is about 800lbs.; I think they would bear 2000lbs.; I have never been able to burst one when well made, when lapped and welded.

"The average pressure on the boiler, per square inch, in my ordinary rate of travelling, is about 70lbs; we sometimes may work up to 100lbs. and 120lbs.; but that is a case of great emergency.

"The greatest probable pressure it will be exposed to, is never more than 130lbs.; the safety-valve blows at 70lbs. to the inch; it is generally on the lift on a level hard road. I do not think that the pressure is more than 20lbs. to an inch on the piston.

"The thickness of the iron of the boiler is about the eighth of an inch; the thickness of my working cylinders about three-quarters of an inch; they have also ribs round them.

"I have always found the most perfect command in guiding these carriages; suppose we were going at the rate of eight miles an hour, we could stop immediately. In case of emergency we might instantly throw the steam on the reverse side of the piston, and stop within a few yards. The stop of the carriage is singular; it would be supposed that the momentum would carry it far forward, but it is not so; the steam brings it up gradually and safely, though rather suddenly. I would say within six or seven yards. On a declivity we are well stored with apparatus; we have three different modes of dragging the carriage. There is no difficulty in guiding the carriage which is drawn; it is peculiarly connected, so that the fore wheels of the carriage drawn, follow the tracks of the hind wheels of the steam-carriage drawing, although making a circle of fifteen feet in diameter. Both carriages could be turned in a circle of ten feet, inner diameter.

"The carriage drawn, with its load, should never exceed three tons, and the carriage to draw it should never exceed the weight I have previously stated, about two tons, or 50 cwt.; it is possible to draw more than one carriage on good roads, but I do not think it would be a circumstance of common occurrence.

"The principal inconveniences we have met with on our journeys have been minor derangements of some parts of the machinery, such as in the valves of the pump, or by tanks leaking, or something of that kind. I never met with any serious accident, except, perhaps, the first accident at Highgate Hill, in 1826; the carriage was not then complete in reference to dragging. I went up the hill contrary to the expectations of every body present, and the workmen were so delighted at it that they neglected to lock the wheel. The carriage was started down the hill without any drag to it; it became difficultly manageable, ran against a stone, and was upset. This is the only accident I have ever experienced myself; I believe Sir Charles Dance once upset the carriage in a first essay; those are the only accidents of the kind I am aware of."

"It has been stated that one of your engines has blown up at Cheltenham; is that the case?"—"I am not aware of that; I rather believe that the lifting of the safety-valve when the carriage stops, is considered to be a bursting, which I think must be so in this statement. I saw the carriages the day after the accident of the crank breaking, where it is stated to have burst, and certainly the carriage had not blown up then; nothing more than the safety-valve had lifted; I came to Cheltenham the day after the accident occurred."

"What was the nature of the accident which occurred?"—"The breaking of one of the cranks, occasioned by the extra difficulty the carriage was placed in. New stones were laid in a hollow of the road, I am told about eighteen inches deep; the carriage had gone through it twice with twenty passengers; the third time it fractured the axle, from the extra force necessary to get it through; the road was in an unusual state. I saw the passengers of a four-horse coach get down in the stones. I was told at the time, by people of great respectability, that all the two-horse coaches invariably put down their passengers; that the mail was stopped; that there were two waggons and two coaches in the stones stopped at the same time, and that they were obliged to exchange their horses to get through."

"Has any other accident occurred to that carriage, except that you have now stated?"—"Nothing that I am aware of material."

"Have the wheels of your carriages frequently caught fire?"—"Never; I saw the three carriages the day after the accident; neither one had taken fire. I am sorry such an idea should for a moment exist; I think it has been occasioned by misconception or prejudiced mis-statements."

"Is the construction of your boiler and of your fire-place such, that it is impossible for the carriage to catch fire?"—"I believe it to be impossible."

"Do you anticipate, in the course of your experience, that you would be able to overcome that inconvenience of being obliged to charge so frequently?"—"We can now go double the distance; but we should have a weight of water, and a weight of fuel, a greater expense to carry, than if we take in one charge at seven-mile stages."

"Do you not consider that the steam-carriages would be applicable not only to the moving carriages at a rapid rate, but also to moving certain weights at a slower pace?"—"I think it is possible, but it would be very expensive, because I find that when you get below a rate of four miles an hour, the expense in fuel is greater than the expense in horses; if the rate exceeds four miles an hour, then it is cheaper, and it becomes cheaper geometrically over horses as you get up."

"What is the greatest weight which you conceive your steam-carriages could draw after them on a level road, at the rate of four miles an hour, the carriage weighing two tons?"—"Every 10 cwt. in the engine would draw as much as four horses."

"Having ascertained that your carriage boiler will evaporate nine gallons of water in an hour, you come pretty nearly to the expenditure of one-horse power?"—"It does not follow in all cases, that one-horse power will be practically produced from nine gallons; and on the other hand I may state, that I have seen a horse power produced from five and from six gallons."

"You have stated, that if you wished to increase the power of your engine, you would increase the weight of it, and decrease the size of the wheels?"—"It might be done either way; the union of the two is not necessary as far as regards the intensity of power; the quantity of power must be produced by an increase of weight, or by some increased or rapid formation of steam.

"The objection to increasing the size of the cylinder, and applying it to a large waggon, lies in the management; it would be difficult in our present stage of knowledge and experience to manage a large cylinder very rapidly on the road; but I see no other obstacle to great speed; there is no theoretical difficulty. I would wish to state, in connection with my former evidence, with respect to fuel for working slowly heavy carriages, that my opinion was founded on some peculiar laws of momentum lately observed: it is well known that one engine, when worked at a given rate, works expansively; that an engine working at a quicker rate, if a piston only travels half a mile an hour, or fifty feet a minute, it will require more fuel for it to do a given work, than if working at two hundred feet a minute."

"Is not the momentum gained by greater velocity an accumulation of power?"—"I think the advantage gained by certain rapidity of action arises from the inequalities of the road being overbalanced by the momentum of the carriage; when the carriage travels slowly, every inequality, every stone or slight obstacle, partly destroys the momentum, but at a certain speed it overcomes them; there is no actual gain of power by momentum; it is only an accumulation very much like that in a common fly-wheel; and in a carriage on a common road it acts on inequalities as a fly-wheel does, in overcoming unequal obstacles in machinery."

"Do you conceive that there can be no mode by which you could use coal instead of coke, by any smoke-consuming apparatus?"—"I know of no mode that is likely to succeed, nor do I conceive that it is possible to make such a combustion of coals that is likely to consume all the sublimated or volatilised matter; the consuming of smoke or the combustion of smoke is prevented principally by the particles being mechanically mixed with, or surrounded by, carbonic acid gas. I believe it not to be chemically combined."

"Would not the motion of the carriage and the current of air that is produced by going quickly through the air give great facility in the application of a smoke-consuming apparatus."—"If the consumption of smoke depended on the presence of oxygen gas or atmospheric air, which contains it, I think it would; but on my previous reasoning, I do not think the consumption of smoke would be effected by any quantity of atmospheric air. I have made several very extensive experiments on this subject, and the only experiment that I have succeeded in was by passing it through sand mixed with quick lime, by which the carbonic acid was absorbed, and the smoke, as it passed through the mixture, rendered combustible; the carbonic acid was removed to a considerable extent, and left the carbonic oxyde and hydrogen gas in such a free state as to be combustible."

"On the Manchester and Liverpool rail-road, I believe there is a clause in their Act to prevent any nuisance being made by smoke, and coke is therefore used; but in the ordinary rail-roads in Wales and other places coal is used."

"What is the greatest weight, in proportion to its own weight, which any carriage draws on a rail-road?"—"A carriage was originally supposed to draw only three times its own weight on a rail-road; but in some experiments which I made in Wales with Mr. Crawshay, of Cyfaithfa

Castle*, we found, in an experiment, that a carriage draws thirty times its own weight. He has the minutes

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* In the Cambrian newspaper will be found an account of the first experiments at Cyfaithfa, in March, 1830; it is as follows:—

To the Editor of the Cambrian.

"Sir—As I have reason to expect that a report will be sent you of the arrival of Mr. Gurney's steam-carriage at my father's works at Hirwain, and of the experiments made of its powers on a rail-road there, I think it better to inform the public (now so much interested in the subject of steam conveyance) through your medium, of the actual facts that have been witnessed in the experiments made, and under what circumstances.

"Mr. Gurney, at my most earnest request, while I was in London three weeks since, consented to bring one of his steam carriages, which had been built and adapted for drawing coaches on turnpike-roads, to try her powers on our new rail-road on Hirwain Common. I had considerable difficulty in persuading Mr. Gurney to accede to my wishes, principally on the score that he had pledged his exertion and attention to the exclusive point of turnpike-road steam-conveyance, and had declined similar invitations to the one I so much pressed; and upon the ground that his carriage, being built solely for the turnpike-road, would not be as well adapted for rail-roads as though made and calculated intentionally for them.

"The engine was brought from London to Cyfaithfa by a pair of horses, on the wheels used in its usual occupation of steam travelling in the neighbourhood of London, and was here fitted with cast-iron wheels, and otherwise adapted to the rail-road, of which a small piece, similar to that at Hirwain, was laid down for the purpose.

"The engine, with water and fuel, weighed thirty cwt., two-third parts of which weight are calculated to press upon the hind wheels, which are alone attached to the engine. The only experiment capable of being made here was that of starting a dead weight on a single carriage, on a very short piece of road.

"Twenty-three tons of iron, cast in long square pigs purposely, were placed on one carriage weighing twenty-five cwt., which was all that could, without danger of falling, be placed upon it, and the engine attached. The steam being gently thrown on, the engine moved forward with the load to the extent of the range admitted. This experiment was repeated until the load was drawn too far, and the weight which we made upon the occasion; but I believe, in practice, they scarcely exceed five times, or from five to ten."

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broke the rails next adjoining those which were alone strong enough to support it.

" The cast-iron wheels, both under the engine and the load, were in this instance new, and the surface of the rail (also cast-iron) nearly so, though as smooth as it could be rendered by cleaning off the sand.

" Mr. Gurney then proposed to run the engine alone, upon the same rail-road wheels, up the common road to my residence, which he did; and the ascent in this road, which is a perfect inclined plane, is 3¼ inches in a yard, and at the termination (in the entrance of the stable-yard) are sixteen feet in length on a rise of two feet in the sixteen, covered with fresh-broken lime-stone. The engine propelled the carriage with perfect facility up this elevation, and repeatedly turned and cut the figure of eight, in a pitched yard of seventy-six feet long, by forty-eight feet wide, never upon any occasion using more than two-thirds of this room for such turning.

" On the following day, the engine was sent to Hirwain, and placed upon the rail-road, which is a dead level of three miles in length, and in the presence of many gentlemen and engineers, was pronounced to be ready for starting as soon as the steam was up.

	Tons.	Cwt.	Qrs.
" A load consisting of pig-iron weighing exactly . .	10	0	0
Upon five carriages, weighing 16½ cwt each . .	4	2	2
One ditto, fitted with seats, &c.	0	19	0
Upwards of 100 persons, say 100 only, at 120lbs. each	5	7	0
Making together . Tons	20	8	2

was attached to the engine.

" I requested Mr. Gurney to permit me to lay and light the fire, as he had informed me his boiler was capable of getting up steam in ten minutes. I laid the fire myself, and from the moment I applied the light, four minutes and fifty seconds only had elapsed ere the steam was up: many gentlemen and engineers timed and witnessed this fact.

" The engine started with the load attached, weighing, as I before enumerated, 20 tons, 8 cwt. 2 qrs. (and at this time there was an addition of many other persons, to the extent of forty-seven), and drew the whole, without stopping, the full distance of the road, say three

"You stated in your former evidence, that you anticipated that passengers would be carried at one-half the rate by your steam-carriages that they are by the common carriages; what difference in the ordinary expenses of

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miles, in thirty-nine minutes, blowing away spare steam the whole way. After turning the engine, (which had not then a reversing motion), it returned with the same load to the place whence it started, in thirty-two minutes.

"The subsequent days have been devoted to various private experiments and trials, all of which have most satisfactorily proved the extreme capability of the power of raising steam by Mr. Gurney's boiler; and yesterday I again invited several gentlemen to witness a further experiment of the engine upon wheels with wrought-iron rings.

"The result was, that the engine drew a load of 21¼ tons upon the same three miles in nineteen minutes, and returned in eighteen minutes; and after this, the engine itself was loaded with 10 cwt. of pig-iron, making its own weight 40 cwt., and attached to a load of 33 tons, 18 cwt., which she drew at the rate of about 2¼ miles to 2½ per hour; and in this, as in every experiment performed, steam was, during the whole working time, blowing waste. The wheels were quite new, never having before been used, and consequently giving an advantage in adhesion to the engine, which probably will not be found when the rings of the wheels have assumed a smoother surface.

"In the trials upon cast-iron wheels, the wheels had been more worn, and were comparatively smooth.

"Having faithfully detailed the principal experiments performed up to yesterday, I shall only call the attention of your readers to the following points:—In all the cases named, Mr. Gurney's engine has drawn from 15 to 16½ times her own weight, upon a level road, and has produced more than sufficient steam for the purpose: that the surfaces of the wheels have been in the first experiments of cast-iron, and in the latter of wrought-iron; and that in all cases the rails of the road were of cast-iron, and have been laid down and in constant work only within the last twelve months, and are consequently at this time in a more favourable state for the performance of a locomotive engine than they probably will be when more worn and polished.

"I am, Sir, your obedient servant,

"WILLIAM CRAWSHAY, Jun."

"Cyfaithfa Iron Works,
18th March, 1830."

carriage would it make if you had a paved road for this purpose?"—"I think that it would reduce the expense to one-half again."

"If there were properly paved roads, you conceive that passengers might be carried at one-fourth the present expense?"—"Not exactly; because the total expense includes the government duty, tolls, &c. as the same; but as far as the steam-power is concerned they would. These subjects have been inquired into by a mathematical friend of mine, and he has published the result of his inquiries."

"I have used my carriage both on snow and on ice. On ice, a little roughing of the wheels is necessary, in the same manner as you rough horses, and little power is sufficient to propel the carriage, because under those circumstances the power necessary to draw the weight is considerably reduced, and therefore the full power of the engine is not necessary to be exerted: in deep snow, there certainly is great difficulty; but I have no doubt that as the subject goes on improving, all those practical difficulties will be overcome."

"I have had occasion, in two or three instances, to use the carriage under circumstances, of ice below, and snow above, with a view to judging of the practical result; and I have not found any difficulty in its progress. The snow is pressed strongly under the wheel, becomes almost immovable, and furnishes a good fulcrum for the wheel; a little preparation only is necessary, and a very little is sufficient to overcome any moderate obstacle of that kind."

"To what velocity could you increase your present rate of travelling with your engine?"—"I have stated that the velocity is limited by practical experience only; theoretically it is limited only by quantity of steam: twelve miles, I think, we might keep up steadily, and run with great safety. The extreme rate that we have run is between twenty and thirty miles an hour. The carriage, when upset by Sir Charles Dance, was at that time going at eighteen miles an hour, but no injury happened either to the machinery or the persons upon it; still I am of opinion, that that speed might be maintained with perfect safety by a little experience in practical management."

The stoppage of Mr. Gurney's carriage upon the turnpike road between Gloucester and Cheltenham, is thus accounted for in Mr. Stone's evidence before the Committee of the House of Commons. The carriage had run regularly from the 21st of February to the 22d of June inclusive, but was stopped by the breakage of the axletree, in consequence of an unusual quantity of stones laid down upon that part of the road that was always the most difficult to pass over; but no accident as to the bursting of the boiler, or any other thing took place, that occasioned any unpleasantness, or any thing like a serious accident, as to injuring any persons. It occurred about a mile and a half from Cheltenham, and it came back all the way to Gloucester, notwithstanding the axletree being broken. One of the engines was able to work during that time; and, of course, having only one engine, when it came to a hill, the men were obliged to assist it over the centre, as there was no momentum. We had on other occasions several little stoppages from defective tubes, of which the boiler is constructed; but nothing accrued from that, except stopping the progress of the carriage.

"What is the greatest number of passengers you have taken on that carriage?"—"Thirty-six passengers and their luggage; but being a short stage, there is never much luggage. The greatest weight we could draw by that carriage, at the rate of ten miles an hour, is from forty to fifty hundred weight. The greatest weight we ever drew on the common road, at a rate of from five to six miles an hour, was eleven tons; we made the experiment on the Bristol road. The weight of the drawing-carriage was upwards of two tons; it drew five times its own weight. The eleven tons, I have stated, included the weight of the drawing-carriage; and I did not consider that the maximum power. We draw the nine tons with only the power communicated through one wheel. I think the tire of that propelling-carriage was five inches wide. A mile and a quarter was the distance which we continued to draw the nine tons. The road varied in its inclination a little; the greatest elevation could not be more than one in twenty-five for twenty or thirty yards; on the average of the mile and a half it was an undulating road, hard and good."

"Were there fourteen inches of stone laid on the road at the time the accident happened of the breaking of the axletree?"—"Yes, there was. When the stones were levelled, they measured seven inches; but at that time they were merely laid across the road, so that the carriage could not pass them without going through them."

In 1831 several trips were made by Mr. Ward in and about Glasgow with one of Mr. Gurney's carriages, similar in its construction to those on the Gloucester and Cheltenham road. These experimental trips were, however, not of a nature the owners could have wished. This carriage had been hastily put together, and shipped off to Leith. On the voyage the engines received some injury, which not being perfectly repaired, occasioned disappointment.

A trip was however made with nine passengers on the steam-carriage, from Glasgow to Paisley, and back by Renfrew to Glasgow, at the speed of between nine and ten miles an hour.

The experiment on the Bristol road, near Gloucester, as to the power of one of these steam-carriages above-mentioned, was made by taking off the hind wheels, so as to reduce the speed and gain power. A pair of three-feet wheels were used on the hind axle, and the engine drew with ease a large waggon loaded with cast-iron. After going about a mile and a quarter, a cart, also loaded with cast-iron, was attached to the waggon. The engine started with these loaded carriages, and returned to Gloucester. The additional weight made so little apparent difference to the engine, that in the way back several persons among the spectators got up and rode; the number altogether amounted to twenty-six. The waggon and cart were weighed at the toll-gate, and found to amount to seven tons, eight hundred weight; this, with the twenty-six persons, made nearly ten tons. This was done with only one wheel attached to the engine. Going into Gloucester there is a rise of about one in twenty, or twenty-five. The wheel did not slip, and there was no occasion to bolt the other wheel. The road on which the experiment was made is comparatively flat and hard.

It is a matter of great regret, that any interested individuals should have it in their power to delay a national benefit by their opposition. A pamphlet has been published by Mr. Gurney, detailing some of the difficulties he had to encounter. The proceedings, which interested persons took, against the invention, are described in a postscript to that pamphlet; it is here quoted in the words of Sir Charles Dance to Mr. Gurney.

" *Hertsbourne Manor Place, Feb.* 3, 1832.

" Dear Sir,

" I have read the copy of your pamphlet, which I return herewith. I think you are right to publish it, for although the Report of the Committee of the House of Commons, last October, is very satisfactory, it cannot be generally known to the public. If you think the following *facts* will be of any use, you are welcome to state them on my authority.

" My steam-carriages ran between Gloucester and Cheltenham regularly four times a day, for four months, from the 21st of February to the 22nd of June, 1831, during which time they carried nearly 3,000 persons, and travelled nearly 4,000 miles. They performed the distance (nine miles) in fifty-five minutes, on an average, and frequently did it in forty-five. There were *sometimes delays*, owing to defective pipes in the boiler, which prolonged the time, but no accident, hurt, or injury, ever happened to any person whatever; the engines were never out of order, and are as perfect now as they were at first. Steam-carriages can be worked profitably, so as to carry passengers for *one-half* of the prices at present charged by horse-coaches.

"Obstacles are always thrown in the way of a new invention, particularly if it is likely to produce important results, from the prejudices of those who have not fairly examined its merits, and by the opposition of others who expect *their interests* will be affected by its success. Thus objections have been made to these carriages, by various descriptions of persons, viz. country gentlemen, trustees of roads, farmers, coach-proprietors, coachmen, postboys, &c. &c. Some said they would be injurious to agriculture; others, that they would destroy the roads; others, that removing horses would ruin the farmers; and others, that it would ruin the coach-proprietors, and throw all the hands employed by them out of work. To these I replied, that the land which is used to keep one horse would keep eight people, and consequently, that the removal of one thousand horses would feed eight thousand people; that the cheap and expeditious mode of conveying passengers, and carrying every thing to market, would eminently tend to the *welfare of all classes*, agricultural and commercial; that the roads would suffer less injury from the broad wheels of steamers than from the horses' feet and narrow wheels of the present stage-coaches; that coach-proprietors would get more custom by carrying people at half the present prices, and would require less capital than in the present *uncertain* outlay for *horses;* and that coachmen, postboys, and horsekeepers would also be benefited, as *more* men are employed about a steam than a horse-coach, in *addition* to the *increased* employment of artificers. The truth of these my arguments and opinions is fully confirmed and supported by the Report of the Committee.

"It will naturally be asked, if the coaches were successful, why they stopped running? I think this most important to be *truly* known to the public.

"I have given a general *idea of the opposition* which was made to our undertaking. Understanding that the trustees of the Gloucester and Cheltenham road were urged by the opponents of the undertaking to concoct measures for preventing the carriages running, on the 20th of June I addressed a printed letter *to the 'Trustees of the Gloucester and Cheltenham Road,'* pointing out the advantages to be expected from the introduction of steam-carriages, which I concluded with the following sentence:—

"'Having received encouragement from some of the leading members of the late and present Administrations, as well as from many distinguished persons in my own and other professions, I have come amongst you with the intention of establishing Mr. Gurney's invention, believing that it will be of the greatest benefit to the country. That it is daily gaining ground in public estimation, is evident from the *increasing number of passengers;* and I cannot believe that the enlightened body of gentlemen whom I now have the honour to address, *will seriously resolve to obstruct* such an undertaking, sanctioned as it is by the King, and encouraged by the first people in the country.'

"This was on the 20th of June; on the 22nd it was reported to me by my engineer, that large heaps of stones were laid across the road about four miles from Gloucester, eighteen inches deep! which the engine had passed over twice (in going to and returning from Cheltenham), with considerable difficulty; and that it was so unusual a mode of repairing a road (which was in excellent order, and required no repairs) that it must be a most serious obstruction to all descriptions of carriages*. The steamer was, in consequence of this difficulty, eighty minutes making the journey from Cheltenham with seventeen passengers†.

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* That it was an *unusual* mode of repairing a road is seen from Mr. M'Adam's evidence (Rep. p. 91), wherein it is stated, that "it is usual to abstain from all general repair of the roads from the middle of April to the middle of October;" and the inference we draw is, that it was also a *hostile* mode.

† "DEAR SIR, "*Gloucester, June* 23, 1831.

"I am exceedingly sorry to inform you that we have broke the hind axle. Yesterday morning we found the road filled up with loose stones for a considerable way near the four-mile stone. The carriage with difficulty went through them, and also returned through them again without any mischief; but the third time the strain broke the axle between the throws. The horse-coaches have been stopped in the stones. The clerk at the branch bank of England says, that he came across by the mail this morning, and that it was also stopped. Mr. Todd, of Cheltenham, says that he was obliged to get down from the coach he came to town by, and that the horses could not get it through. The Champion, from London, a fine four-horsed coach, was brought up, and, in whipping to get through, broke the harness to pieces. Waggons are obliged to get extra horses; in fact, the proceedings are most unaccountable. It is some relief, however, to know that the steamer has gone through where horses have been brought up; and I hope soon to get the axle mended.

"Many curious reports are abroad: it is said coach proprietors have done this; I am persuaded, however, this is not the case. Though interested men, they are far too respectable for an act of this kind. I believe there is no doubt who has been at the bottom of it.

"We have made altogether 396 regular journeys, making 3,644 miles in all. Our expenses in coke altogether 78*l*. One-third of this coke has been burnt in exercise and experiments when we were not running. I have taken the carriage to pieces to mend the axle, and find the engine not worn or injured; and, with the exception of the brasses on the crank, there has been no perceptible wear of any part.

"I am, dear Sir,

"Yours faithfully and obediently,

"*To Goldsworthy Gurney, Esq.*" "JAMES STONE."

"The steamer proceeded as usual to Cheltenham, in the afternoon of the same day, with sixteen passengers, and was again eighty minutes on the journey. On returning from Cheltenham, with nearly the same number of passengers, the axletree broke about two miles from Cheltenham (before it reached the place where the stones had been laid down), which I attribute to the strain it had received in the morning from so unusual a resistance occasioned by the stones.

"It was represented to me by a great variety of persons, who offered to come forward if necessary, that the obstruction on the road was so great and so unusual to the stage-coaches, as well as carriages of all descriptions, waggons, carts, &c., and even the mail, that I was urged to represent it to the postmaster-general to indict the trust, or to take some other legal mode of redress, against an act which was generally believed to be wilfully committed, for the purpose of obstructing the steam-carriages.

"I was resolved, however, not to do any thing hostile, if possible; and felt only pity and contempt for those who could resort to such means for preventing a great national undertaking. But as I was convinced the public were daily growing more pleased with the conveyance, passengers from all parts of the kingdom declaring their satisfaction and cordial wishes for its success; and the lower classes expressing their conviction, that the substitution of steam for horses would tend to their comfort and relief, it was my intention to have strengthened my wheels, and to have gone on in spite of any obstructions. But, in the course of the following week, I learned that a vast number of turnpike bills had passed, and that more were passing through both houses of parliament, granting tolls upon steam-carriages, which would be a complete prohibition; and that the Cheltenham trust was one of the number. Feeling that we were thus likely to be defeated by acts of the legislature, in addition to the other difficulties, I relinquished my intention of continuing to run the carriages, and hastened to London, where I arrived in time to consult with you as to your petitioning parliament, which led to the appointment of the Committee of the House of Commons. I remain, dear Sir,

"Yours most sincerely,

"C. W. DANCE."

"*To Goldsworthy Gurney, Esq.*"

In a letter from Sir Charles's engineer it is said, "there have not been many minutes' difference in the time of making each journey. I attribute the difference mainly to the different qualities of the coke, as I have had different mixtures of coals made into coke, in order to ascertain, if possible, which would answer the best; and partly to the different stokers having to keep up the fire. The time has been kept with the greatest accuracy; but I have only registered the passengers booked, and who paid fares: we took a large number who did not pay. We have charged less than one-half of the horse-coach fares for the last three months. This is a very bad place to commence on: we are surrounded with prejudiced people—agriculturists, coach-proprietors, coachmen, stable-boys, and others directly or indirectly connected with them; these, with the old ladies of Cheltenham, I assure you, offer a formidable opposition to any innovation. Whenever we are a few minutes after our time, it is regularly reported we have either blown up or broke down, or both. I am happy to say, however, we have not met with the most trifling accident, up to this time."

ACCOUNT of the JOURNEYS made by the Carriage between Cheltenham and Gloucester, distance Nine Miles. Extracted from the Journals.

Days of the Month.	Minutes of each Journey.	Days of the Month.	Minutes of each Journey.	Days of the Month.	Minutes of each Journey.	Days of the Month.	Minutes of each Journey.	Days of the Month.	Minutes of each Journey.	Days of the Month.	Minutes of each Journey.
1831.		1831.		1831.		1831.		1831.		1831.	
Feb. 21	55		55		48		58		56		46
	62		60	Mar. 29	60		52		55		60
	50	Mar. 11	55		50	Apr. 16	58	May 5	60		62
22	50		60		58		48		60	May 23	60
	60		58		48		60		70		45
	58		60	30	50		56		60		70
	60	12	58		50	18	62	6	90		55
23	50		55		55		58		65	24	55
	40	14	54		45		122‡		75		54
	50		45	31	60		78		60		55
	55		60		50	19	56	8	80		50
24	50		56		60		42		58	25	58
	55	15	55		60		55		75		48
25	50		56	Apr. 2	55		55		70		65
	60		55		50	20	51	9	55		50
	62		58		60		48		48	26	60
	60	16	55		50		80		60		55
26	50		56	4	60		60		47		60
	55		75†		48	21	60	10	56		50
	60		80		58		47		50	27	62
	60	17	60		55		60		56		60
27* 28	60		58	5	50		48		52	28	60
	55		60		57	22	60		60¶		56
	50		57		58		47		58		75
	57	18	55		40		75	11	60		60
Mar. 1	57		60	6	58		50		47	30	120§
	55		55		48	23	50		55		80
	60		45		58		60		55		70
	62	19	60		49		70	12	55		55
2	63		50	7	60		50		55	31	80
	50		55		58	25	67		55		55
	55		55		49		59		55	June 1	75
	49	21	55		47		50	13	55		48
3	50		60	8	60		48		48		65
	40		58		54	26	55		60		50
	50		56		60		54		60	2	65
	48	22	69		58		56	14	56		60
4	47		55	9	61		57		48	3	160‖
	46		50		58	27	40		50		60
	46		47		60		70		50		75
	50	23	55		58		80	16	55		60
5	55		55	11	60	28	60		48	4	60
	60		55		58		65		56		60
	60		55		58		60		56		70
	58	24	55		60		60	17	54		65
7	50		46	12	61	29	50		54	6	80
	60		55		55		50		64		62
	50		55		60	30	80		58		75
	60	25	48		54		60	18	60		60
8	45		50	13	57		65		48	7	60
	55		45		52		60	19	58		60
	60		55		82	May 2	52		58		70
	62		60		55		58		54		60
9	60		58	14	55		55		56	8	78
	60		55		61		60	20	55		68
	60		50		59	3	60		52		60
	60	28	60		55		58		57		
10	48		55	15	60	4	60		50		
	60		58		58		55	21	62		

* The Carriage did not run on Sunday. † New Stoker. ‡ Guide motion deranged.
¶ On this trip thirty-eight passengers were conveyed by Steam. § Pump valve unseated. ‖ Same again.

Thus we have a tabular view of 315 journeys by a steam-carriage; and bearing in mind that this was the first attempt at a regular public conveyance, and that it was opposed in every way by a body of ignorant and selfish persons, the proof of practicability is very strong.

The disappointment to Sir Charles, occasioned by an ignorant and prejudiced party, who had opposed him in every way, was sufficient reason for his retirement from the field for some time. In 1833 he came to London with his steam-carriage, and had it repaired by Messrs. Maudslay, Sons, and Field. The result was, a patent taken out in the joint names of Sir Charles Dance and Mr. Field, for improvements in the boiler. (See Chapter IV.)

On the 18th of September, I accompanied the patentees in a short experimental run upon measured ground, when I found that the steam-drag and omnibus attached, had travelled steadily $2\frac{1}{10}$ miles, at the rate of sixteen miles an hour. A trip to Brighton was in consequence determined on, and the following are notes of the journey.

Left Messrs. Maudslay, Sons, and Field's Factory, Lambeth, in Sir Charles Dance's Steam-carriage, in all Fifteen Persons, 20th September, 1833.

Mile-stone		Hrs.	Min.	Sec.	REMARKS.
		8	18	..	
1½	From Westminster Bridge .	..	24	..	
2	. . . . .	..	26	30	
3	. . . . .	..	32	..	Beginning of Brixton Hill.
4	. . . . .	..	39	..	Top of ditto.
5	. . . . .	..	44	20	
6	. . . . .	..	50	20	
7	. . . . .	..	55	50	
8	. . . . .	9	..	45	
9	. . . . .	..	5	40	Croydon.
10	. . . . .	..	11	25	
11	. . . . .	..	18	..	
	Stopped for water, coke, &c. .	..	18	40	
	Started . .	..	29	..	
12	. . . . .	..	35	15	
13	. . . . .	..	41	22	
14	. . . . .	..	47	35	
15	. . . . .	..	54	..	
16	. . . . .	10	..	55	
17	. . . . .	..	7	55	
18	. . . . .	..	12	55	Merstham.
19	. . . . .	..	19	55	To this distance the roads were exceedingly wet and heavy.
20	. . . . .	..	24	40	Commencement of good road.
21	. . . . .	..	31	55	This mile is Red Hill, which it will be seen was ascended in 7 min. 15 sec.
22	. . . . .	..	37	50	
	Stopped to take in water, &c. .	..	40	10	Salford Mill.
	Started . .	..	48	30	
23	Not observed .	..	..	..	
24	. . . . .	..	58	20	
25	. . . . .	11	3	20	
26	. . . . .	..	7	5	
27	. . . . .	..	12	52	

Mile-stone		Hrs.	Min.	Sec.	REMARKS.
28	. . . . .	..	19	40	Crawley.
29	. . . . .	..	24	40	
30	. . . . .	..	30	45	
31	. . . . .	..	38	20	Up a long and heavy hill.
	Stopped for water and coke .	..	42	10	Black Swan, Peas Pottage Gate.
	Started . .	12	3	20	
32	. . . . .	12	6	15	
33	. . . . .	..	12	..	
34	. . . . .	..	18	50	
35	. . . . .	..	28	..	This is down a very long hill, and the place at which the carriage was stopped on its former trip, having on that occasion done the distance in 3 h. 24 m., inclusive of 21½ minutes' stoppage for taking in water. In the present trip, the two hind wheels of the omnibus were skidded, and therefore required the force of steam to draw it down hill.
36	. . . . .	..	36	10	
37	. . . . .	..	41	40	
38	. . . . .	..	47	10	
39	. . . . .	..	52	55	
40	. . . . .	..	58	35	
41	. . . . .	1	3	45	
	Stopped for water, &c. . .	..	10	..	
	Started . .	..	17	30	
42	. . . . .	..	21	10	
43	. . . . .	..	29	40	
44	. . . . .	..	52	..	Here the carriage stopped 20 minutes, owing to the coke having clinkered so much that it was impossible to get the fire to burn, and it will be seen that the remainder of the journey took up much more than the average time of going.
45	. . . . .	2	2	50	
46	No. 46 mile-stone on the road .	..	..	..	
47	. . . . .	..	6	10	
48	. . . . .	..	12	30	
49	. . . . .	..	18	30	
50	. . . . .	..	26	5	
51	. . . . .	..	32	30	
52	Brighton Church .	..	40	15	

	Hrs.	Min.	Sec.
Thus the journey was completed in	6	22	15
Deduct stoppages	1	6	
Time of running	5	16	15

Gentlemen present.—Sir Charles Dance; Mr. Field, manufacturing engineer; Mr. J. Maudslay, manufacturing engineer; Mr. Lowe, civil engineer; Mr. Alexander Gordon, civil engineer; Mr. Winson, engineer; Mr. W. Carpmael, civil engineer; five Gentlemen, friends of Sir C. Dance and Messrs. Maudslay and Field.

Left Brighton (Gloucester Hotel) in same Steam-drag and Omnibus, 21st September, 1833.

Mile-stone		Hrs.	Min.	Sec.	REMARKS.
..	Brighton Church .	10	28	30	By London time.
51	. . . . .	..	36	45	
50	. . . . .	..	42	30	
49	. . . . .	..	47	15	
48	. . . . .	..	54	40	
47	. . . . .	11	..	..	
46	. . . . .	..	..	..	There is no 46 mile-stone, in consequence of the measure being made through Cuckfield, and the two roads join near this spot; the distance is somewhat shorter by the Red Hill road.
45	. . . . .	..	3	30	
44	. . . . .	..	8	20	
43	. . . . .	..	13	20	
42	. . . . .	..	18	45	
	Stopped to take in water and coke	..	20	..	Red Hill road.
	Started . .	..	31	15	
41	. . . . .	..	35	10	
40	. . . . .	..	40	10	
39	. . . . .	..	46	5	
38	. . . . .	..	53	35	
37	. . . . .	12	2	..	
36	. . . . .	..	7	40	
35	. . . . .	..	14	35	
34	. . . . .	..	21	40	Here the four-horse coaches have two post-horses to assist them up the hill.
33	. . . . .	..	27	5	
32	. . . . .	..	32	..	
	Stopped to take in water and coke	..	35	..	
	Started . .	..	45	..	
31	. . . . .	..	48	..	
30	. . . . .	..	53	3	
29	Not observed .	..	..	..	Crawley.
28	. . . . .	..	3	45	
27	. . . . .	..	10	45	
26	. . . . .	..	16	15	
25	Not observed .	..	..	..	
24	. . . . .	..	25	35	

Milestone		Hrs.	Min.	Sec.	REMARKS.
23	Not observed .	..	..	..	Passed two coaches which left Brighton at ten o'clock, a four-horse and a two-horse; these coaches passed the steam-carriage whilst taking in water.
	Stopped to take in water and coke	..	34	45	
	Started . .	..	49	..	
22	. . . . .	..	52	..	
21	. . . . .	2	..	..	Overtook the two-horse coach.
20	Not observed .	..	..	..	
19	. . . . .	..	12	..	The coach kept the middle of the road, and would not permit the steam-carriage to pass; obliged to permit steam to escape, and coming to a hill, the horse-coach got a little start, and changed horses.
18	. . . . .	..	19	15	
17	. . . . .	..	24	45	Passed the coach whilst changing horses.
16	. . . . .	..	29	40	
15	. . . . .	..	34	30	
14	. . . . .	..	39	40	
13	. . . . .	..	44	30	
12	Short of coke .	..	49	50	Passed 4-horse coach whilst changing horses.
	Stopped to take in water and coke	..	54	30	The fire having become very low, owing to being short of coke.
	Started . .	3	15	30	
11	. . . . .	..	16	10	
10	. . . . .	..	25	..	Croydon.
9	. . . . .	..	30	55	
8	. . . . .	..	35	50	
7	. . . . .	..	41	50	
6	. . . . .	..	46	40	
5	. . . . .	..	54	10	
4	. . . . .	4	2	10	Here clinkers were found to be formed on the tubes which supported the fire; stop of a few minutes. The fire being low, had lessened the speed for the last few miles.
3	. . . . .	..	8	35	
2	. . . . .	..	18	30	
..	. . . . .	..	24	..	

	Hrs.	Min.	Sec.
Thus having completed the journey from London to Brighton, and from Brighton back to London, without any failure of machinery, in	5	55	30
Deduct for stoppages for taking in coke and water	0	56	0
Actual time of running	4	59	30

Gentlemen present.—Sir Charles Dance; Mr. Field; Mr. Maudslay; Mr. Alexander Gordon; Mr. Carpmael; five Gentlemen, friends of Sir C. Dance and Messrs. Maudslay and Field; Mr. M. Ricardo, and Mr. Busby, came with the carriage some miles: and some individuals were taken up and put down on the road.

On the 10th of October, 1833, I accompanied Sir Charles Dance in a steam trip to Beulah Spa, near Norwood. Time was marked in the same manner as on the Brighton trip just mentioned. There were present, Sir Charles Dance; Mr. Macneill, C. E.; Mr. T. Maudsley, C. E.; Mr. Field, C. E.; Mr. Cubitt, C. E.; six others, and myself. The distance, seven miles, was gone in 46 minutes 30 seconds, being nine miles an hour. We returned in 36 minutes 30 seconds, being at the rate of 11½ miles an hour. This road is very hilly.

On the 12th of October, 1833, the same steam-drag and omnibus was put upon the road between Wellington Street, Waterloo Bridge, and Greenwich, where it continued to run for a fortnight, with the view of showing the public in London what could be done. There never was any intention on the part of the proprietor of making it a permanent mode of conveyance, and therefore he kept the company select by charging half-crown tickets each way. Several engineers of eminence were now anxious to have the carriage tried on the Holyhead line of turnpike road to Birmingham, where the tractive power requisite is well known. I have given it in the Appendix (C.) I was accordingly employed, to prepare coke and water-stations all the way there. The following Report was the consequence.

Report of the Result of an Experimental Journey upon the Mail-coach Line of the Holyhead Road, in Lieut.-Colonel Sir Charles Dance's Steam-carriage, on the 1st of November, 1833.

PUBLIC attention having been attracted to the practicability of travelling with locomotive engines upon ordinary turnpike roads, by a Report of a Committee of the House of Commons, of the 12th of October, 1831, stating that, in the opinion of the committee, the practicability of such mode of travelling had been fully established; and more recently by a Report of a journey to and from Brighton having been successfully performed by Lieutenant-Colonel Sir Charles Dance's steam-carriage, as well as by the fact that the same carriage was daily in use between London and Greenwich, conveying numerous passengers through the crowded suburbs of the metropolis without the slightest inconvenience to the public, we were desirous of personally making an experiment of the facility with which a carriage of that description could perform a journey of considerable length: and having selected the mail-coach line of the Holyhead road for the purpose of such experiment, we made an arrangement with Sir Charles Dance for the use of his carriage, on Friday, the 1st inst.

	Tons.	Cwt.
* The weight of the carriage, with the water, coke, and three persons upon it, was about . .	3	5
* The weight of the omnibus-coach attached to it .	1	0
* The weight of the passengers, their luggage, and some additional sacks of coke, about . .	1	15
* Making the gross weight moved . . .	6	0

* The motive power was an engine with two cylinders, seven inches in diameter and sixteen inches stroke. The pressure of steam on the tubes constituting the boiler, or generator, was adjusted to 100 lbs. per square inch.

Before the carriage had proceeded six miles, one of the tubes of which Sir Charles Dance's boiler is composed was found to leak so fast as to render repair absolutely necessary: it was also apparent, that the size of the engine was not sufficient to carry so great a weight along a heavy road † at any high velocity.

" * These facts have been ascertained by Mr. Joshua Field, Mr. John Macneill, and Mr. Alexander Gordon, Civil Engineers."

† See Appendix (C) for the tractive power required on this road.

The weather was by no means favourable, there having been much rain in the course of the night and morning, so as to make the road heavy, added to which the winter coating of new materials had in many places been laid upon the road. Notwithstanding these obstacles, upon our arrival at Stony Stratford, 52½ miles from town, it was found by Messrs. Macneill and Carpmael, who had taken accurate minutes of the loss of time occasioned by stoppages, that the average rate of travelling had been seven miles per hour.

There can be no doubt (i. e. from what was observed), that with a well-constructed engine of greater power, a steam-carriage conveyance between London and Birmingham, at a velocity *unattainable by horses*, and limited only by safety, might be maintained; and it is our conviction that such a project might be undertaken with great advantage to the public, more particularly if, as might obviously be the case, without interfering with the general use of the road, a portion of it were to be prepared, and kept in a state most suitable for travelling in locomotive steam-carriages.

THOS. TELFORD,
President of the Institution of Civil Engineers.
JOHN RICKMAN.
Commissioner for Highland Roads and Bridges.
C. W. PASLEY, Colonel Royal Engineers.
BRYAN DONKIN, Manufacturing Engineer.
TIMOTHY BRAMAH, Civil Engineer.
JAMES SIMPSON, Manufacturing Engineer.
JOHN THOMAS, Civil Engineer.
JOSHUA FIELD, Manufacturing Engineer.
JOHN MACNEILL, Civil Engineer.
ALEXANDER GORDON, Civil Engineer.
WM. CARPMAEL, Civil Engineer.

London, November, 1833.

It will be seen more clearly hereafter (in Chapter IV.) that this last carriage was, in fact, a modification of Mr. Gurney's, and it will be observed in the history of other steam-carriages, that they are all indebted, in some, cosiderable measure, to that gentleman. It must have given Mr. Gurney no small degree of satisfaction, when nearly three years after his retirement from the field of locomotion, he found his Petition to the Commons House of Parliament so well received as it was on the 29th of April, 1834; when Sir William Molesworth presented the same, praying for Alteration of the Tolls upon Steam-Carriages plying upon Common Roads, and wherein Mr. Gurney complained that the Legislature had thought fit to insert in numerous road bills, clauses enacting prohibitory tolls on steam carriages (see page 64): hence that capitalists had been deterred from employing his carriages, the public deprived of the best and the cheapest means of locomotion, and the petitioner's time and fortune sacrificed without obtaining the just reward of his important discoveries. After showing in a brief manner to what perfection the petitioner had brought his invention (see page 88), and the causes of these enactments, Sir William showed how the agricultural interest became alarmed at his success, and how they reasoned in the following lucid manner:—"Steam-carriages," they said, "will supersede carriages with horses; consequently there will be a diminution of demand for horses; consequently the same quantity of oats will not be required; farmers will be ruined, and rents will fall. To avert these evils, Mr. Gurney's carriage was violently stopped by the trustees of the Cheltenham road, and a vast number of road bills were hurried through both houses of parliament. These bills imposed tolls upon steam-carriages of from six to twelve times the amount of the tolls levied upon stage coaches with four horses. Mr. Gurney immediately petitioned parliament. A committee was appointed to investigate this subject. "In consequence of the report of that committee, a bill was brought in, to alter the tolls, which bill received the sanction of this House, and was rejected by the wisdom of the Upper House." Sir William then referred to the Report of the Select Committee of the Commons (see Appendix F.), and demonstrated to the House that locomotion on the common roads, by means of steam, was not only perfectly feasible, but that all the objections urged against it were groundless.

"By means of the prohibitory tolls, this nation (Sir William said) may be deprived for a time of the advantages which must necessarily result from the employing inanimate instead of animate power. But one may confidently predict that steam-carriages will run upon the roads of this kingdom *when the names of those individuals will entirely be forgotten, whose ignorance and whose petty interests* have induced them to oppose this important application of elementary power.

"That in this country, which owes its superiority to the successful application of mechanical spirit and invention, whose inexhaustible supplies of fuel enable its inhabitants, by means of inanimate power, to produce cheaper than any other nation on the earth, to whom consequently all facilities of locomotion are of the utmost importance; that in this country prohibitory tolls on steam carriages should exist, is a circumstance of which an enlightened legislature should surely be ashamed.

"There is a peculiar hardship in the case of Mr. Gurney, which arises out of our patent laws. Any experiments performed by an individual in public, become the property of that public, unless he has previously obtained a patent for them; and he cannot secure them in any subsequent specification. In order to illustrate the evil which this law produces, I must observe that there are two distinct stages in most inventions. First the individual discovers some general principle, which he conceives may be applied in some particular manner to attain the end which he aims at. He then proceeds to put this principle into practice; in so doing he finds various difficulties of detail, which it was impossible for him to have estimated *à priori;* these difficulties he gradually removes; others arise, perhaps, in their stead, which again are removed; till ultimately, after a considerable lapse of time, the invention is perfected. No invention of importance, I may affirm, ever sprung at once, perfect in form and in shape, from the head of its inventor. It ever requires successive alterations and additions to complete it. If these operations can be carried on by the inventor alone, and in seclusion, he may hope to perfect his invention before he takes out his patent. If, however, of a kind which must be performed in public, and with numerous assistants, the inventor must first take out a patent, and consent to sacrifice a portion of the duration of that patent in making experiments, otherwise he would be debarred from reaping the exclusive advantage of the experiments. Mr. Watts expended fourteen years, the whole period of his patent, in making the necessary trials, ere he completed one steam-engine. Government granted him a renewal of his patent, in consideration of the expenditure of time and capital. Cartwright likewise expended the period of his patent in making necessary alterations: he received a pecuniary compensation from government. Mr. Gurney's inventions hold the same rank in the scale of utility with the discoveries of those gentlemen. The legislature have dealt with him in a far different manner, and have prevented him from reaping, by the approval of the public, the natural reward of his discoveries. Mr. Gurney's experiments could only be performed with publicity. As his carriages were to move on the roads, it was on the highways that his experiments were made. Mr. Gurney was obliged to take out his patent ere he made a single public trial. He calculated that four or five years of his patent would be expended in alterations and additions, of the necessity of which those trials would convince him; he hoped that the remaining period would remunerate him. I find that his patent is dated 1825, that his carriage started from London to Bath in 1829, was established between Gloucester and Cheltenham in 1831, and that in the same year these road bills obtained the assent of the legislature. Thus the just and reasonable expectations of Mr. Gurney, have been annihilated: in a few years his patent will expire, the public will reap the advantage of his inventions, and the inventor himself will be a ruined man. I need not dilate further on the hardship of this case. The house, I feel convinced, will see the necessity of repealing these enactments, and if others, better qualified than myself, do not bring forward a measure with reference to that object, I shall feel it my duty again to bring this subject under the consideration of the House." The Hon. Baronet concluded his speech by reading the Petition, of which the following is a copy:—

"To the Honourable the Commons of the United Kingdom of Great Britain and Ireland in Parliament assembled.

"The humble Petition of Goldsworthy Gurney,

"Sheweth,

"That in the year 1825, a patent was granted to your petitioner for propelling carriages by steam on common turnpike roads, and that, in consequence of the legal protection thus afforded, he commenced an extensive series of experiments on the subject. The novel and difficult nature of the inquiry presented numerous obstacles in practice, which required considerable time, and a succession of extensive trials and experiments, to overcome. That at last, when by five years' arduous application, he had succeeded in removing them, and had publicly proved its practicability and value, by establishing a steam-carriage in the public service, then, and not till then, the legislature hastily passed certain Acts of Parliament, compelling him suddenly to suspend all further proceeding That up to this time, and for the four months preceding, the public were daily carried (Sundays excepted), with a profit to the proprietor, at one-half the fares of horse-coaches, in less time, and with perfect safety. That when the practical working of his patent was thus suspended, preparations were making for its general introduction in the public service, by which he expected to obtain a return for the great expense he had incurred. That on being compelled to suspend the further prosecution of his patent, he immediately presented a petition to the House of Commons, and a committee was appointed to inquire into the subject, by whom it was closely investigated during the period of three months; in the course of which time the evidence of the first statistical and engineering authorities was taken before them. The committee reported to the house that they 'considered its practicability fully established;' that 'tolls to an amount which would utterly prohibit its introduction had been imposed;' that 'the substitution of inanimate for animal power was the most important improvement in the means of internal communication ever introduced;' and that they 'recommended legislative protection to be extended to it with the least possible delay.' That up to the present time these prohibitory acts have never been repealed, and in consequence your Petitioner has been compelled to retire from further prosecution of the subject, without being able to obtain any personal compensation, or even remuneration, from his patent, after having expended on it the whole of his property, and the best years of his life. That the workmen employed in the experiments were necessarily discharged, and while some have carried the information obtained at his expense to engineers now engaged in the same object, others have attempted to start carriages to his prejudice, which, in connection with the legislative suspension of his patent, has occasioned an opinion of the practical failure of his invention. That the term of your petitioner's patent is now nearly expired, and he is thus deprived of every prospect of fair benefit, advantage, or even remuneration from it, on the faith of which he had been encouraged to expend upwards of thirty thousand pounds, without a single failure in its principle or practical working; therefore your petitioner humbly prays, that your honourable house will now be pleased to take the extreme hardship of the case into consideration, and, as recommended by your committee of a former session, repeal the legislative restrictions which have deprived him and the public of the practical advantages of his invention, and he will ever pray, &c.

(Signed) "GOLDSWORTHY GURNEY."

Sir George Cayley supported the prayer of the petition. He considered Mr. Gurney as a very ill-used man. On the faith of our patent laws, Mr. Gurney had given up, to pursue this noble invention, a lucrative profession; five years' toil, and at an expense of thirty thousand pounds, brought it into practical use :—yet he is now deprived of receiving any remuneration,—not from any want of success in his experiments,—not from any failure in his carriage,—but by act of parliament: "by our act and deed has he been wronged, and by our act and deed ought he to be, and I trust ultimately will be, redressed.

"The great opposition to this discovery seems to have arisen from a jealousy on the part of the agricultural interest, who appear to be afraid that because there are now about a million of horses employed in this kingdom in drawing carriages, if the power of steam were substituted, agricultural produce would fall in price. Surely no such fears need be entertained, when we know that in the United Kingdom the births exceed the deaths every day by nine hundred, and that hence to-morrow we shall have a population of nine hundred more than we have to-day. I think we need be under no apprehension that steam-carriages can be built with such rapidity as to displace horses with greater speed than human mouths can be supplied to consume corn. Is it nothing that by eventually ceasing to keep a million of horses, we shall have room for eight millions of human beings more than at present? But I look to even higher prospects than this as the result of steam-carriages: I believe that they will eventually produce that desirable degree of free and rapid intercourse between all nations, which will, in times, though far distant, induce one common language, and universal peace among the children of men."

Mr. Jephson, Chairman of the Committee of the House of Commons, on steam-carriages, in 1831, and who had been concerned in drawing up their report, felt himself called upon to say that how favourable soever that report is to Mr. Gurney's invention, subsequent inquiry, and the subsequent experiments made with his steam-carriages, have convinced him that no report could be too highly laudatory or recommendatory of this important invention. The mechanical difficulties which presented themselves, Mr. Gurney had, in almost every instance, triumphantly surmounted, and it was therefore a serious hardship upon him to have been prevented, by these enactments, from practically introducing his important invention, with the eminent success it merits, to the public. Shortly after the report was presented to the house, he (Mr. Jephson) had introduced a bill for regulating the tolls to be put upon steam-carriages: the bill passed this house, but was lost in the upper house, owing partly to the lateness of the session, and partly to the desire expressed by some of the noble lords to have time allowed them for investigating the whole matter for themselves. The investigation took place, but ere it concluded, the session was too near its close to allow of the bill being passed. No one regrets more than he did the situation of Mr. Gurney, whose talents, and whose almost miraculous inventive faculties, have laid the foundation of incalculable advantage to the nation, and of fortunes to individuals. He trusted Mr. Gurney's reward would be adequate to his merits: though it has too often happened that the originators of inventions most serviceable to man, have themselves derived no advantage from those inventions; and he (Mr. Jephson) trusted that the justice and sense of gratitude in the country towards one whose inventions so well entitle him to the name of a benefactor of his country, will not allow Mr. Gurney to become one of those flagrant instances of national neglect and ingratitude.

Mr. Wallace thought that Mr. Gurney's invention had laid the foundation of far higher benefits to the country than even the slip-dock invented by Mr. Morton, who very properly obtained a grant of public money, rather than a renewal of his patent; and he hoped the same measure of justice would be dealt out to Mr. Gurney; and he trusted parliament would signally reward Mr. Gurney as the creator of such an all-important invention as locomotive steam-engines for common roads.

Mr. Caley observed, " It is true that but too many instances have occurred of national ingratitude and neglect towards the creators of inventions of public importance: too many of these public benefactors have died in poverty and neglect. But these instances occurred in the time of our unreformed parliament; for then the people were naturally jealous of their money being voted away to any purpose, however laudable, by a house which did not represent them; and particularly because their money was voted to sinecurists and parties who had never merited it. The real representatives of the people who now sit in the house, will, I am sure, on the contrary, express their abhorrence of such treatment of men of science, by acknowledging and rewarding, to the full extent of their merits, all public benefactors like Mr. Gurney, for they will be aware that at the same time they are doing an act of individual justice, they are serving the best interests of the country. I very cordially support the prayer of the petition."

Mr. C. Buller considered Mr. Gurney a public benefactor, "and I trust that the house will comply with the prayer of his petition. It has been but too often charged against us, as a national stigma, that we suffer men of talent and science, whatever services they may have rendered to the community by their inventions and discoveries, to lie neglected and indigent; that in but too many instances we have failed to discover, or at least acknowledge, a man's worth till he is dead. Such has been the disgraceful charge made against us. We are now, however, a 'reformed' parliament; but if we really wish to merit that glorious title, it will be necessary for us to pursue a different course in this particular, as in others, from the old parliament; and I trust the house will, in the case of Mr. Gurney, evince that they are really a reformed house. A comparison has been instituted between Mr. Gurney's case and that of other engineers and men of science, who have (singularly happy they) received the support of parliament under particular circumstances. The parallel does not hold good. In the latter cases no interference on the part of government had taken place, and the parties were rewarded simply because the perfecting of their patent had required the whole duration of their patent: but in Mr. Gurney's case the legislature has interfered, and virtually suspended his patent, by imposing tolls on his carriages, so heavy as to amount to prohibitory, and this too at a point of time when he had expended all his money, his time, and a good portion of the duration of his patent; and when he had proved to the satisfaction of all reasonable men, that his invention was one of the most perfect and complete kind, and that its general introduction and use, would be of the most eminent public advantage. His case, then, calls more particularly for parliamentary interference, and I trust the house will show that they agree with me in my opinion by supporting him in the prayer of his petition. Mr. Gurney's complaint is, that he has been prevented, by these legislative enactments, from introducing his inventions: these enactments, and no defect in the carriage, have prevented Mr. Gurney from bringing it into general operation, beneficially to the public and to himself; and it is therefore the more incumbent upon the legislature to redress the injury they have thus done him. Mr. Gurney, however, in his petition, does not apply for compensation, however well he is entitled to it. His modest and reasonable request is simply that the restrictions thus placed upon his honest and beneficial industry may be removed. When he has fully persuaded the public of the peculiar and all-important advantages of his invention, then it will be for this house to consider whether they are not in justice bound to give a suitable reward to a man who has done and sacrificed so much in his prosecution of a great national object. I, for my part, think the question should be met at once, under the peculiar circumstances of the case, for I would not have this act of national justice deferred, as has been too often the case, till the object of it has sunk into the inactivity of old age, or the oblivion of the tomb."

Mr. Petre, Mr. Rotch, and other members, supported the prayer of the petition.

The petition was then ordered to be laid on the table.

Mr. Walter Hancock, of Stratford, completed a carriage in the summer of 1831. Plate VIII., fig. 2, is a sectional view of one of those in which I have repeatedly taken a trip. A is the fire-place, the fuel being laid upon the bars which are seen between the fire-place and the ash-pit, B. The ash-pit is made air-tight, or nearly so, in order that the blast from the revolving fanners in G may be urged upwards through the fire. The fire-place is also necessarily kept close. It is provided with eye-holes, through which the fireman (who sits on a small seat behind the boiler) can view the state of the fire. Fresh supplies of coke are dropped through the feed, or hopper, P Q. On this feed, are placed double doors, one of them being always shut to prevent the blast escaping up Q P when the coke is added to the fire. The boiler is more particularly described in Chapter IV. Steam is supplied to the engines, D, of which there are two (see p. 38), through R, and is regulated in quantity by a slide valve, S. The alternating vertical motion of the pistons in the engine cylinders, is changed from the parallel motion, T, to the continuous circular motion of the cranks upon E, by the connecting rod, V, as already described (p. 20). Only one cylinder and its connections can be shown in this "section." Two shives or sproket-wheels are placed upon the crank-shaft, E, and two also upon the axle, F. An endless pitch chain passes round each pair of shives, and conveys the motion from E to F, and from thence to the hinder wheels.

It is necessary to keep the centre of E and the centre of F always parallel to, and equi-distant from, each other, in order that the pitch chains may be in an equal state of tension; this is managed by means of two rods, one on each side of the carriage; the rods vibrate upon F as a centre, and cause the crank axis, E, when the carriage is jolted, to describe a larger or smaller segment with the same radius, as the body in which the engines are placed plays up or down upon the springs. By this means concussions which affect the wheels, do not distress the machinery. The radius rods are constantly vibrating, but the steam-engine is securely and perfectly suspended upon flexible steel springs.

Passengers are seated above the water-tanks, H H. K is a connecting rod by which the guide (at L) can open or shut the throttle-valve, S, and supply himself with what steam he requires, or shut it altogether off when stopping.

The whole engines, crank-shaft and two throws, together with the pumps, are supported by flexible springs, which provide for any concussion on rough roads. The wheels turn loose on the axle, and one or other, or both, are fixed by a clutch when required. This clutch is on the outside of the wheel, and can be screwed out or in, as the case demands, with great facility. The turning of the carriage round to the off-side is prepared for, by throwing out the off-side clutch, and keeping in the near one, and the turn-round to the near-side is prepared for, by throwing out the near-clutch, and throwing in the off-side clutch. A little play is left between the catches in each clutch, so that a winding road may not oblige either wheel to be disengaged; and it is only in a short turn, or a turn round, that the clutch must be shifted, and this can be done in a very small space of time.

The fire is urged by the blower G, which is driven by a connection with the engines. The waste steam is blown from the engines into the chimney, and so destroyed.

The passengers are carried on the same machine, Mr. Hancock preferring that disposal of the weight to the dragging of it in a carriage behind.

The wheels of this carriage are a beautiful exhibition of strength and lightness combined. The spokes are all wedge-shaped, and where they are fastened into the nave abut against each other. Their escape laterally is prevented by a large iron disc at each end of the nave; and these being bolted through, confine the spokes very securely in their place.

Every eight miles he takes in water and coke; about 7 cwt. of water, and sometimes eight: it depending upon the state of the roads, consuming most steam when the roads run heavy. About four bushels of coke are used for each stage.

The average time is about twenty minutes in getting up the steam, and he does not consume more than a bushel of coke for this purpose at first starting. The fore part of the vehicle is for passengers, so that all the machinery is quite behind the carriage, and the fore part of the carriage is entirely for the convenience of passengers, being made of greater or less length according to the number of persons.

The guide sits in front, at L, and steers by means of a wheel, O, placed horizontally, as in Mr. Gurney's carriage, with this difference, that instead of the vertical spindle having a pinion at P, it is made with a horizontal drum or shive, upon which the middle of a chain is fastened; the ends of the chain are attached to the different ends of the fore-axletree, in such manner that one or other of the fore-wheels may be hauled forward to turn the carriage. One important improvement in the guide-motion has been made by Mr. Hancock, which is by means of a friction-strap or band, at P, passed round a small friction-drum; the guide can, by pressing a pedal with his foot, tighten this band on the drum when the carriage does not require to be turned out of the straight course. When the carriage is thus held in its line of direction, the guide's hands may be released from the tiller-wheel, O, for the jolting of the wheels over rough pavement or other inequalities of a road, are not sufficient to slip the friction-band. In case of requiring to turn, the guide's foot is either relaxed or taken off the pedal, and the tiller, O, worked by his hands. This band is of great importance in many cases, and by it, a guide with feeble arms may steer as well as a Hercules.

This carriage is capable of carrying sixteen passengers, besides the engineer and guide. The weight of it, inclusive of engines, boilers, coke, and water, but exclusive of attendants and passengers, is about $3\frac{1}{2}$ tons. The wheel tires are $3\frac{1}{2}$ inches wide. The diameter of hind wheels 4 feet. The width of tire is not considered by the patentee to be so objectionable in practice as it might be considered. This he accounts for, by the variable nature of the roads, "a broad wheel on gravel is considered to be an advantage; it is however on a great disadvantage on a road between wet and dry; but in those latter cases we have always an overplus of power (steam) blowing off at the safety-valve." Blowing off steam, either from the safety-valve, or from the engines, creates no nuisance, because it is injected "into the fire in every direction," and so destroyed. The carriage can be turned in little more than ten feet, and stopped in much shorter space than any horse-coach.

A metallic band, pressing upon the outer part of the wheel, is applied as a drag or break, when descending hills.

In slippery roads, or steep hills, both hind wheels are connected to the engine, in order to increase the adhesion to the road; but in general one driving wheel is found to be sufficient.

Mr. Hancock, in October 1832, determined to make a trip to Brighton.

On Wednesday, October 31, this steam-carriage came from Stratford, through the streets of the city, at the different speeds necessary to keep its place behind or before other carriages, as occasion required, and took up its quarters on Blackfriars Road, to prepare for the following day's trial. Accompanied by a scientific friend, a distinguished officer in the navy, I joined Mr. Hancock's friends on the next morning, making eleven passengers in all. We started at the rate of nine miles an hour, and kept this speed until we arrived at Redhill (where all the coaches at this season require six horses), which we ascended at the speed of between five and six miles an hour. The bane of the journey was an insufficient supply of coke and water; the water, indeed, we were obliged to suck up (with one of Hancock's flexible hose-pipes) at such ponds and streams as we could find. These difficulties delayed the completion of the journey (subsequently performed by steam in less than five hours) till next day; but on our return our speed was much increased, and one mile was accomplished up hill, at the speed of seventeen miles per hour.

On the 11th September following, Mr. Hancock steamed again to Brighton; on the 12th he exhibited his carriage, in action, to several distinguished persons there, and steamed to London on the 13th. Owing to delays to take in water, there being no regular stations, the time occupied, *including* stoppages, was long; excluding stoppages, less than six hours was said to be the time occupied in running.

In April 1833, Mr. Hancock started a steam omnibus from the Bank of England to Paddington. The carriage was the property of some individuals, amongst them several who had been engaged as stage-coach owners, on that road. The following may be relied on as a correct statement of the actual performance.

1833.	Miles.	Total time.	Delays.	Travelling time.
		Min.	Min.	Min.
April 22, From City Road to Paddington, thence to London Wall, and back to City Road	10	68	18	50
23, From City Road to Paddington and back	8½	71	9	62
24, Ditto ditto ditto . . .	"	64	11½	53
25, From City Road to Paddington and back to the middle of Pentonville Hill, where the pressure of the steam broke the piston of the off engine				
26, Put in a new piston double the strength of the former. From City Road to Paddington and back .	8½	49	5	44
27, Ditto ditto ditto . . .	,,	50	5½	44½
29, Ditto ditto ditto . . .	,,	51	5½	46½
30, Ditto ditto ditto . . .	,,	51	6½	45
May 1, From City Road to Paddington, thence round Finsbury Square, and back to City Road . . .	10	78	15	63
2, Ditto ditto ditto . . .	,,	67	9	58
3, Ditto ditto ditto . . .	,,	79	18	61

The average quantity of coke used was three bushels each journey.

At this time Mr. Hancock was summoned before a magistrate, for not working the carriage under a hackney-coach plate, and was fined a mitigated penalty. The Stage-coach Act was made to embrace all kinds of stage-coaches except steam-coaches; the latter being exempted in order to encourage them. The Hackney-coach Act was made to embrace all other descriptions of public conveyances within certain distances of London; thus Mr. Hancock was prevented running as a stage-coach, although application was made at the Stamp Office. He was, even there, in my presence, refused a hackney-coach plate. It is needless to detail the disputes which now sprang up between the company and the patentee, in which the latter appears to have been ill-used. Difficulties and disappointments were the consequence, and this carriage ceased to ply for passengers.

Mr. Hancock has, in every instance, exhibited perfect control over his engine, in guiding, turning, stopping, and backing. He is now engaged building a sufficient number of carriages, with which, it is understood, he intends to establish and maintain a regular conveyance for the public. This he had hitherto been prevented or thwarted in, either by legislative interference (perhaps inadvertently permitted), or by disputes amongst joint-stock proprietors, who are too seldom free from that bane of co-operation, selfish purpose.

Colonel Macerone and Mr. Squire's steam-carriage (plate VIII. fig. 3) is a fine specimen of indomitable perseverance. Their operations have resulted in the quickest steam-carriages yet running. Accustomed, as aid-de-camp to Murat, king of Naples, to follow that dauntless cavalry officer, Colonel Macerone still retains a love of quick motion. Eighteen and twenty miles per hour is nothing uncommon.

The engines are arranged much like Mr. Gurney's* (plate IX.) in the treble perch of the carriage.

The boiler, A, (plate VIII. fig. 3) is explained in a subsequent chapter, and the fire is urged by a centrifugal blast, B, similar to Hancock's, placed behind the carriage, beside the seat of the fireman. On top of the blower, coke boxes, C, are placed within reach of the fireman, whose seat is at D.

Passengers are carried on the same wheels with the engines, in an open carriage body, the seats of which are formed upon water tanks.

Colonel Macerone has published the work of his steam-carriage in some interesting and admirably written pamphlets †, to which readers are recommended. In one of them he says, "The rail-road engines on the Manchester and Liverpool line, cost on an average fifty pounds a month, each, in repairs!" Out of twenty carriages in hand, they have often had only six in a working state! It can be proved, that the carriage produced by Mr. Squire and myself, has run on *common roads* 1700 miles, without requiring *any* repair! For this assertion Colonel Macerone has been much written against by parties who never went even to see his carriage. My own opinion, formed after narrowly watching and riding much upon this carriage, is, that it has done, and can do again, more work than 1700 miles, without repair. I do not, nor do the proprietors assert, that after running such a distance it required no repair. I know, and Colonel Macerone never concealed, that it does require repairs.

* Mr. Gurney, indeed, considers this steam-carriage to be a modification of some of his arrangements: Mr. Squire having been Mr. Gurney's carpenter some years ago. I cannot, however, find that Mr. Gurney has made such arrangements public; and I incline to think that *if* the Colonel and Mr. Squire have made this carriage out of the *debris* of Mr. G.'s factory, they have the more merit.

† Effingham Wilson, Royal Exchange, publisher.

There are two cylinders, each with a stroke $15\frac{12}{16}$ inches. Steam ways, each $2\frac{4}{16}$ inches × $\frac{13}{16}$ of an inch, and $7\frac{1}{2}$ inches diameter.

Not to mention numerous short trips by this carriage, I have chosen to give my notes of two trips to Windsor and back. The distance is $23\frac{1}{2}$ miles. In September, 1833, eight of us, besides Colonel Macerone, Mr. Squire, and a fireman, in all eleven persons, were conveyed at the rate all the way, as noted.

We made another trip to and from the place with the same carriage, and with the same number of passengers, in October following.

On both occasions I took the time with one of Arnold and Dent's chronometers; and the observations were made sometimes upon one mile distance, sometimes upon two miles, and sometimes upon three miles.

September, 1833.		October, 1833.	
13 Observations in 23 miles. *Going.*	8 Observations in 19 miles. *Returning.*	12 Observations in 22 miles. *Going.*	Observations. *Returning.*
Rate in miles and tenths of miles per hour.	Rate in miles and tenths of miles per hour.	Rate in miles and tenths of miles per hour.	Rate in miles and tenths of miles per hour.
11.	11.7	9.7	5.
12.4	9.1	10.	6.3
12.2	6.2	11.	7.5
12.4	5.8	11.5	8.2
11.6	9.	9.7	10.
10.6	11.8	12.	
13.6	8.4	10.5	Too dark to see the mile-stones, and the speed not allowed to exceed 9 miles in the dark.
14.	11.3	9.5	
13.2		9.	
9.6	Stopped at $3\frac{1}{2}$ miles from London, by breakage of an ill-welded axletree.	9.6	
11.		9.6	
11.		12.6	
11.			

The falling-off of speed when returning, as on column first, was owing to clinkers in the fire.

The falling-off of speed when returning, as on column second, was in consequence of the fireman having burnt his hand when thoughtlessly putting coke on the fire without his shovel.

On the 26th of April, 1834, I travelled five miles from the patentee's premises, and five miles back again, at the average speed of 13 miles an hour. But the quickest journey I have taken any note of was on the 4th of October, 1833, to Edgware and back again, a distance of 16½ miles, in one hour six minutes and thirty seconds, exclusive of stoppages for water, an *average* duly performed for this distance of *fifteen miles per hour*.

Messrs. Ogle and Summers built a steam-carriage in 1831. Mr. Summers, in his evidence before the select committee of the House of Commons, stated that their carriage had steamed along for 4½ miles at the rate of 30 miles an hour. In December, 1833, Mr. Ogle, accompanied by several gentlemen, proceeded from the Bazaar, in Portman Street, to the residence of Mr. Rothschild, on Stamford Hill. The distance of seven miles was accomplished, notwithstanding the crowded state of the roads, in thirty-one minutes. With this carriage Mr. Ogle on a previous occasion performed a journey from Southampton to Birmingham, Liverpool, and London. The boiler is described in Chap. IV.

Mr. Joseph Maudsley is now building a steam-carriage, which he intends either for the highway or railway. (See Chap. IV.)

Mr. Palmer is building a carriage at Messrs. Bramahs. (See Chap. IV.)

Mr. Roberts, of Manchester, built a steam-carriage in April 1834, which, after running well for a few miles, burst the boiler.

Messrs. Manton, gun-makers, are building a steam-carriage. If successful, it will be the subject of a patent.

Messrs. Fraser, Redman, Phillips, Rich, and about twenty others, are now building steam-carriages in England; some hopeful, some hopeless.

Messrs. Maudslay, Sons, and Field, are now building an experimental carriage for the promoters of the "London, Liverpool, Birmingham, and Holyhead Steam-coach and Road Company," upon Mr. Field's arrangement.

It is much to be regretted that there are many builders engaged in constructing steam-carriages who have disregarded the experience furnished by Mr. Gurney. We could adduce many instances wherein excellent engine-builders have altogether failed in making a steam-carriage; and other instances wherein, after a great expenditure of money and time, they could not compete with that gentleman.

Mr. Russell, of Edinburgh, a gentleman of great mechanical knowledge, and who lectured upon natural philosophy, from the chair of the late Sir John Leslie, until the election of Professor Forbes, has for about a year and a half, been engaged in building one or more steam-carriages. That gentleman is known to have written an article upon "the present condition and future prospects of steam-carriages," in the Foreign Quarterly Review (October, 1832), and his polite acknowledgment of my labours should certainly disarm my criticism, were it not that I consider that article exhibits errors of a dangerous character.

"From all that has yet been made public," says the Foreign Quarterly, "we are only warranted to deduce this one conclusion—that every attempt yet made to render steam-carriages the means of economical and regular inland communication has totally and absolutely failed.

"Reduced to this condition, it may be well to inquire into our prospects. Is there, we may ask, any peculiarity in the nature of land locomotion to prevent that power which turns the wheels of a *boat* from propelling, with similar effect, the wheels of a *britchka!* Is there any thing in the nature of a carriage so peculiar, that while a steam-engine can do the work of 100 horses, it cannot do the work of 'four-in-hand?' Have we attained the 'hitherto and no farther' of the power of steam? Knowing, as we do, that the proposed substitution will bring about a great and beneficial change in the moral, political, and commercial state of the empire, are we at last, after hopes so long and so fondly cherished—so long pregnant with apparent fruition, doomed to discover that we have only been tantalised?" * * * * "Can the government do nothing to forward the invention and bring it to maturity?"

"Till the time of Watt, it (the steam-engine) scarcely existed in a form more important than a philosophical toy. He produced it at once what he has left it to us, a perfect engine. Since his day we have done nothing, added nothing, improved nothing. * * * * We may have effected a trivial saving of fuel it consumes, or the quantity of space it may occupy."

What? Before the days of Watt, could we not empty our mines of water, and could we not do a variety of other simple work? The invention by Watt of the separate condenser, no doubt was attended by a saving of fuel in such operations, but have not the improvements in the economy of fuel increased that economy three-fold since his days? and, is not such a three-fold saving more than a "trivial saving?" The great national advantage resulting from Watt's ingenuity was his adaptation of it to machinery; and to say that we have done nothing, when we have extended that application to machinery, is a great error. As to the "perfect engine" which Watt left to us, it was totally unfit for locomotion, and, to use the Reviewer's own illustration, no more fit for that purpose than an elephant is for rope dancing.

That the failure of steam-carriages has certainly not been (says the Reviewer) "in the nature of the thing to be done, but in the mode of setting about it." I agree with him, but I do not think that there may be "detected in each invention omissions," and "elements of self-destruction necessarily involving total failure," as he would lead his readers to believe" * * "in the great principles of structure and arrangement."

The reviewer furnishes his readers with "five tests as criteria of the value" of steam-carriages.

In the *first* he objects to all the boilers yet published. In the *second* he says the steam is ill conducted from the boiler to the cylinders.

"A single turn in the direction of a pipe will deprive the steam of 1-10th of its power; and every successive turn a similar portion. If, therefore, the direct pressure of the steam in the boiler be such as would raise 1000lbs, and it had to turn one corner before entering the cylinder, it would only raise 900lbs." * * * "No engine has yet been made that has less than two or three such turns to encounter, and hence 1-6th or 1-4th of the power is always wasted."

If this be the case, I have tried the experiment to little purpose. The Reviewer is mis-informed. I have known many instances contradictory of this. To name but one;—a 10-horse boiler supplied a 10-horse engine, 60 feet distant, and the total difference of pressure after *seven turns*, was only 6lbs. per square inch of 55lbs. that is to say, the steam of the boiler was at 55lbs. (per mercurial gauge), and the steam at the piston (per mercurial gauge) was 49lbs.; this loss of 6lbs. is to be accounted for, mainly by the steam having lost its heat in travelling so far. The loss alluded to can only be accounted for by loss of caloric, or by friction; and if the latter be insisted on, I have my own and other experience in the flow of aeriform bodies through many miles of pipe, twisting and turning into the various alleys of the metropolis. The loss of pressure by friction is so small, that, on a windy night, the undulations of the gas-holder are observable in every burner, six or seven miles length of main from the station.

In the *third* criterion the reviewer insists "that *one* cylinder is equal in capacity, and preferable to *two;*" an untenable assertion in the present state of the steam-engine, and one quite unnecessary for any body to dispute about.—The momentum is so often destroyed by slow going, rough roads, and stoppages.

In the *fourth* criterion the Reviewer says, "imperfect suspension has been the ruin of every machine that has yet been constructed." Our answer is, that it was not the ruin of Gurney's; and from what has been shown (page 108), that it is not likely to be the ruin of Hancock's.

In the *fifth* criterion is required "an engine of variable power, like that of a horse." If this be not already furnished by *the blast,* it ought to be; for the blast or artificial draft, can, and in many carriages does, regulate the power admirably.

In April, 1834, Mr. Russell's carriage was established as the regular conveyance betwixt Glasgow and Paisley; and in a letter from Mr. Russell (21st April) he informed me "that during the last week they have gone every trip (seven miles and a half) in forty or forty-five minutes."

Several schemes have been tried for locomotion, by means of men's power working-wheels, treadles, levers, or oars. But from experience in the velocipede, proposed for homo-locomotion, and extensively used as an instrument of exercise and amusement thirteen years ago, the most admirable contrivance of the kind ever exhibited, it was found that a man, " sound in wind and limb," could walk or run five miles on his feet with greatly less labour than he could wheel himself the same distance on a velocipede. The inexplicable vital principle bestowed by the omnipotent God upon his creatures, cannot be superseded by man's utmost knowledge in mechanical science.

Messrs. Heatons, Brothers, steam-drag has been much talked of. The boiler and fire-place are very much like those of the locomotive engines in use upon the Liverpool and Manchester railway (described in our Chapter upon Boilers.) This machine is placed on four wheels, the front and hind wheels being of much the same size and relative proportions as those of other heavy carriages. The frame, or rough body for the engines, boiler, and machinery, is placed upon the springs, which are situated upon the ends of the axletrees, near the inside of the naves. The front axletree is straight (i. e. not cranked) and fixed; the wheels turning upon it, as in other carriages. The axle of the two hind wheels is also straight, and not cranked. The boiler is swung upon the frame on springs, with the fire-place projecting beyond the hind wheels. At the farther end of this boiler, and in the centre of the body, are placed two vertical cylinders, each seven inches diameter and twelve inches stroke, and under them is the water tank. Above the two cylinders, and extending across the carriage, is the crank-shaft, with the two cranks at right angles, to which the two piston rods of the two engines are immediately connected. Upon this crank-shaft are three toothed wheels, which communicate the power to three similar toothed wheels upon another cranked shaft, which is placed parallel to the crank-shaft of the engines. These wheels are made so as to slide upon the shaft when it is desirable to alter the relative speed of the carriage and the engines, and the patentees are by this arrangement enabled to employ a greater power when ascending an inclined plane, by making the carriage travel slower, whilst the engines are working with the speed at which they are constructed to work with the greatest advantage. (See page 26.)

The carriage is propelled by the adhesion or friction of the hind wheels upon the road, the connexion from the engines to these wheels being made in the following manner:—On the spokes of each hind wheel is fixed a ring of smaller diameter than the wheel, upon the periphery of which are teeth. These teeth of the ring work into corresponding teeth in a smaller toothed wheel, fixed on a crank-shaft above, the centre of which is parallel to the centre of the hind axle. This last-mentioned crank-shaft is put in motion by the second crank-shaft, which we spoke of, and by this arrangement the power of the engines is communicated from the engine crank-shaft by means of toothed wheels to another crank-shaft; from thence the power is communicated by two horizontal connecting-rods to another crank-shaft, and from thence it puts the driving or hind wheels of the carriage in motion, by means of other toothed wheels. These numerous parts may reasonably be supposed superfluous, when the simple arrangement of Mr. Hancock (see p. 108, also plate VIII., fig. 2) is known. The hind wheels of Messrs. Heatons' carriage are loose upon the axletree, but furnished with ratchet teeth, which may be acted on by corresponding catches fixed on the ends of the axle, so that either wheel is allowed to advance farther than the other in turning a corner. The arrangement for turning is very similar to other steamers. The steam is supplied and regulated, or stopped off from the engines, by means of a clog, in which the guide's foot is placed; by the flexion or extension of his leg the clog is moved backwards or forwards, and the throttle-cock is opened or shut; thus the guide's hands are at perfect liberty to steer the vehicle.

In the month of August, 1833, the patentees had a very good run with a steam-drag of the above description, but in ascending the Lecky Hill, near Birmingham, on the road to Worcester, part of the machinery was broken. This injury was in a few days repaired, and on the 28th of August they proceeded from their factory in Shadwell Street, Birmingham, to try the same road. Attached to the steam-drag was a stage-coach, weighing 15 cwt., with fifteen passengers, about a ton weight, thereon. They picked up five more passengers shortly after starting, and arrived at Northfield, a distance of nearly seven miles, in fifty-six minutes. After taking in water, which occupied nine minutes, they started, and proceeded to ascend Lecky Hill, a rise of one in nine, and in some places one in eight. Many parts of the hill were very soft; but, by altering the connexion from the engines to the wheels, as we have above described, the drag, with the coach attached and nine persons, were conveyed to the summit, a distance of 700 yards, in nine minutes. After proceeding to Bromsgrove, the drag and carriage returned, and on descending the steepest part of the hill, they proved their power, by stopping suddenly. This Lecky Hill is certainly one of the worst upon any turnpike line in England. The coke consumed cost 2*s.* 6*d.* for this twenty-nine mile run, being rather less than half a bushel per mile.

The above account I have been obliged to cull from various sources; part of it I received from one of the patentees, and the whole was confirmed by Mr. Macneill, who has witnessed the carriage travelling. The patent having merged into a company, managed by directors, I was refused permission to examine the carriage.

Mr. Gurney considers that even men of great practice, as engine-makers, may, from their slight experience in steam-carriages, fail in accomplishing their purpose. He contends, and with some reason, that little if any thing has been done beyond what he did in 1829. Certainly his experience has been much neglected by some other builders, and hence the failure of so many steam-carriages. Can projectors, trusting altogether to their own calculations, negligent of amassed experience by Gurney, Hancock, Macerone, and Squire, be expected to succeed? We trow, no.

CHAPTER IV.

BOILERS.

WHEN we look at the varied construction and arrangement of boilers, we are led to inquire the reasons for the obvious dissimilarity before us. Some, indeed, have lightness and safety as two features in common; but the mass of them would lead to the supposition that lightness was the alone object of their formation, that perfect safety was unattainable, and that an explosion would either,—by some happy chance or superior management,—not take place, or be attended by death only to some of those whose situation could be supplied on the morrow at equally low wages.

Our object in this chapter shall therefore be, to examine a few boilers,—selected from the numerous schemes now on record or made public,—which have been constructed with the view to both of those important results desirable in locomotive science, LIGHTNESS and SAFETY.

A boiler may be light in itself, but if by its use fuel be wasted or water be blown away in a liquid state, lightness is not obtained as it ought; fuel and water being ponderous bodies, which must be carried along with the carriage.

In every case, the power obtained is just in proportion to the heat which can be transmitted from the fire to the water, and then be made available in the state of steam actuating the locomotive engine.

The following Table will show the increments in the elastic power of steam which attend increments of temperature. The Table is by Mr. P. Taylor.

Temperature.	Force in inches of Mercury.	Temperature.	Force in inches of Mercury.	Temperature.	Force in inches of Mercury.	Temperature.	Force in inches of Mercury.	Temperature.	Force in inches of Mercury.
212	30.00	234	44.60	256	65.50	278	94.70	300	133.75
213	..	235	45.50	257	66.60	279	96.26	301	135.60
214	31.00	236	46.40	258	67.75	280	97.75	302	137.55
215	..	237	47.30	259	69.00	281	99.25	303	139.75
216	32.30	238	48.20	260	70.12	282	100.70	304	141.90
217	33.00	239	49.10	261	71.25	283	102.20	305	144.05
218	33.70	240	50.00	262	72.45	284	103.80	306	146.15
219	34.20	241	56.90	263	73.52	285	105.60	307	148.30
220	35.00	242	51.75	264	74.80	286	107.30	308	150.65
221	35.50	243	52.62	265	76.00	287	109.00	309	157.70
222	36.20	244	53.50	266	77.23	288	110.80	310	155.00
223	37.00	245	54.40	267	78.50	289	112.65	311	157.20
224	37.50	246	55.30	268	79.80	290	114.50	312	159.45
225	38.00	247	56.25	269	81.14	291	116.40	313	161.75
226	38.80	248	57.20	270	82.50	292	118.30	314	164.20
227	39.50	249	58.20	271	83.90	293	120.25	315	166.70
228	40.20	250	59.12	272	85.45	294	122.20	316	169.15
229	40.85	251	60.10	273	86.95	295	124.15	317	171.70
230	41.55	252	61.12	274	88.50	296	126.05	318	174.30
231	42.25	253	62.15	275	90.00	297	128.00	319	176.80
232	43.00	254	63.20	276	91.55	298	129.80	320	179.40
233	43.75	255	64.40	277	93.15	299	131.62		

The transmission of heat is more or less rapid, according to the surface through which the heat has to pass, and the difference of temperature between the fire on one side, and the water on the other side of that surface. It is neither convenient nor safe to urge a great heat upon a small space. An intense flame may be so directed as that the interchange of particles of water cannot be sufficiently rapid to prevent the formation of an elastic fluid, which prevents the approach of cooler water to that part of the boiler against which the intense heat is acting: the heat not being carried off, would consequently burn the boiler.

It has been said in the preceding chapter, that the source of steam power is heat. For obtaining, therefore, a certain power, a certain quantity of heat must be given to the water, and that heat requires surface for its transmission. But a large surface involves the necessity of a large and heavy boiler, if the boiler be constructed in the old fashioned shape.

The great desideratum in generating steam is, to expose the smallest quantity of water necessary, to the largest heated surface, at a particular temperature; at the same time generating and maintaining a body of steam sufficient for the consumption of the engine. It is well known that in the ordinary boilers a large quantity of water is kept in a boiling state, and only about one-third of the boiler is exposed to the action of the fire; that the steam rises upon the surface, and is collected in the upper part of the boiler,—that the deficiency of water (produced by the creation and passage of the steam from the boiler into the engine) is renewed and supplied by a forcing pump worked by the engine, that the water may be thus preserved in it at an uniform height. To produce steam for a large engine an immense boiler is requisite, containing many hundred gallons. The disadvantages are, that the boiler occupies a large space; that the weight of the water is great, and in steam-carriages particularly the weight and room occupied become a serious inconvenience; and that in case of explosion, to which they are all liable, the effects are awful and destructive.

"It was a desideratum," says Mr. Farey, "for a long time, to contrive a boiler which, being made of such thin metal as would not render it too heavy, should have sufficient strength to retain high-pressure steam without danger of bursting; also that it should expose a sufficient external surface of metal to the fire and flame, and of internal surface to the contained water, to enable the required quantity of steam to be produced from such a small body of water as could be carried on account of the weight; both these conditions were fulfilled by subdividing the contained water into small tubes or into flat chambers, which expose a great surface in proportion to their internal capacity, and admit of being made strong with thin metal; but there is also another condition which is rather incompatible with the two former, viz. that there shall be such a very free communication between the interior capacities of all the tubes or narrow spaces, as will combine them into one capacity, and permit the contained water to run from one to another, and also permit the steam, which is generated in innumerable small bubbles within the narrow spaces, to get freely away from them, to go to the engines without accumulating and collecting into such large bubbles as would occupy the spaces and displace or drive out the water before them; for if that effect take place it produces three great evils; the water boils over into the engines along with the steam and is wasted, and the thin metal which remains exposed, at the outside to the fire, becomes burning hot in an instant, after the water is so driven away from the internal surface, and the further production of steam is suspended, so long as the water continues absent. If such displacement of the water take place frequently, and in many of the narrow spaces at once, the boiler will not produce its proper quantity of steam, and the thin metal will soon be destroyed by the fire, and be burned through."

The ordinary cylindrical high-pressure boiler, with or without hemispherical ends, having a flue-tube through the interior, is too well known to require description. Plate XII., fig. 11, exhibits the cross section of one modification of a high-pressure boiler without any flue through it. The first attempt to deviate from the boiler of large, heavy, and dangerous diameter, which we shall notice, was that of Mr. Arthur Woolf, a gentleman whose name must always stand high in connection with the steam-engine. On plate X., fig. 1, is exhibited a side elevation of this boiler in a simple form, and on fig. 2, an end view. It consisted of several cylindrical vessels connected together. The same letters upon figs. 1 and 2, will guide the eye of the reader to the same parts in the two figures. The smaller horizontal cylinders, a a, &c., were connected by means of the vertical cylinders, b b, &c., to the large or cylindrical chamber, C. The flame and heated air generated in the furnace, D,—heated the first two smaller horizontal cylinders, a a,—reverberated so as to pass below the third, over the fourth, under the fifth, over the sixth, under the seventh, round the eighth, thence descended and passed through the flue, E; the heat then rose under the eighth, back over the seventh and fifth, and so on, till it ascended the chimney. The tubes a a and b b, together with the lower half of C, were filled with water. From this chamber, C, the steam was conveyed by a pipe at the top of the boiler, in the usual manner, to the engine. F, represents the man-hole door, by which the mud and silt were cleaned out from time to time. The cylinders, a a, &c., could have been placed vertically, and in the specification of his patent, Mr. Woolf describes how this may be done. He also recommended the tubes not to be of large diameter, because the larger the diameter of any tube is, the stronger it is required to be for resisting the pressure of the steam. Another view of this boiler, wherein the arrangement is somewhat different, may be seen in the Philosophical Magazine, vol. xvii., p. 40. Mr. Woolf erred in making the tubes of cast-iron; this he did for convenience and economy; but not only was cast-iron objectionable, on account of its liability to fly in pieces when subjected to accidental concussion, but also on account of the greater thickness of metal required. It is now generally acknowledged that the rapidity of transmission of heat is regulated by the thickness of metal, and the formula $\frac{H-t}{\theta}=R$ may be used; where H represents the temperature of the fire, t the temperature of the water, and θ the thickness of the iron, R being the rapidity of transmission.

Mr. Julius Griffiths attempted another modification of a boiler, composed of horizontal tubes. A drawing of the arrangement of pipes in this boiler will be found on plate X., fig. 3. H is the fire-place, the smoke and heated air passed through among the pipes, JJJ, in the direction of the arrows, and from thence to the chimney. The horizontal pipes, JJJ, were 1¼ inch diameter, and two feet long, fastened by flaunches at each end to the vertical boxes, KK, which were the means for the hot water to ascend, and for the cold water to descend. Only six pipes and two vertical boxes are shown at this view of the boiler, but similar rows of pipes and their vertical boxes were placed behind these, making 114 pipes in all. Above the whole, the three chambers, LLL, were placed, as steam room, and from them the engines were supplied with steam. These tubes would not always contain the water, and when empty got so heated that no force pump could inject the water; on this account the invention was abandoned. The steam, as it was generated in the horizontal pipes, passed along to the vertical pipes, from thence to the steam chambers on the top, and from thence to the engines. There is no doubt the failure of the carriage which Mr. Griffiths had made is to be attributed solely to the boiler. The cylinders, pumps, and connections of the locomotive engine made for Mr. Griffiths by Messrs. Jos. Bramah and Sons, were all in the best style of mechanical execution, and had Mr. Griffiths's boiler been of such a kind as to generate regularly the required quantity of steam, a good steam-carriage must have been the consequence.

This observation leads me to a remark applicable in almost all cases, though perhaps not in this, that much money has been expended, and an age of time lost on the one hand by steam-carriage projectors adhering too closely to their own views and rejecting counsel, and from the prejudice of experienced engineers on the other. When engineers of known ingenuity and experience are applied to, their advice should have every weight with the projector.

About this time Mr. Jacob Perkins constructed a boiler of small water-capacity. The boiler was filled entirely with water, and so much heat was forced into the water, that when a valve was opened in a pipe from the boiler to the cylinder of the engine, the water upon being thus liberated instantly flashed into steam of great pressure and rushed to supply the engine. Each stroke of the engine replaced a like quantity of water again in the boiler. Mr. Perkins did not generate any steam in his boiler; he could not do so, for he kept the boiler quite full of water, and allowed the highly-heated water to flash into steam either in the working cylinder of his engine, or in the pipes leading to the working cylinder, a system which has never been successfully adopted; and repeated experiments have given reason to fear that no practical or beneficial effects, will result from such a method of generating steam, particularly for engines of a large size; at any rate no satisfactory public proofs on a large scale, of its efficacy, have yet been furnished; and if the danger be apparent from the explosion of a boiler with a pressure of 30 or 40 lbs. to the square inch, the effects of an explosion from a large vessel, no matter what its substance or strength, filled with water intensely heated, and under a pressure of 800 or 1000 lbs. per square inch, cannot be easily described.

Plate X., fig. 4, is a cross section of a boiler made by the late Mr. David Gordon, in 1825, for a locomotive carriage. It consisted of four cylindrical vessels, A, A, B, B, each five feet long and one foot in diameter, with hemispherical ends, and two smaller cylindrical vessels, cc, of the same length, and six inches in diameter, also with hemispherical ends. The six vessels were made of wrought iron, one-eighth of an inch thick, rivetted and brazed at the sides, and having the heads brazed on. They were all united by what are termed two-way, or breeches, pieces. The height of the water will be seen in A, A. C, C were also full of water. The steam room was in B, B, upon each of which there was a safety-valve. The fire was made at D, and supplied by a blast at E. F was a double case, which enclosed the whole. With water and fuel the weight was 11 cwt., and by means of an intense blast at E, it was found sufficient to generate enough of steam to keep a 6-horse high pressure engine at full work for four hours (the period of the experiment); but no flame or intense heat from the fire being allowed to go higher than the horizontal diameter of the vessels AA, the surface for transmission of heat was much too limited. The fire had been urged the more upon this small surface, and when (after only four hours of work) the boiler was examined, the strength of the under portion of AA, was found to be materially impaired. This arrangement of a boiler was consequently abandoned.

Major McCurdy, a North American gentleman, endeavoured to avoid the necessity for having any quantity of water in the boiler, by an arrangement for injecting water into a small red-hot retort. Upon being brought into contact with the heated surface of metal, the small jet of water instantly assumed an aeriform state, and was allowed to flow into the working cylinder. Had the inventor been able to regulate the heat of his boiler or retort, and the disposal of the water, so very accurately as to generate steam of uniform temperature and elasticity, there might have been some hope of this machine, but such an equability of temperature was impossible: at one time the heat of the retort was so intense, that the water was decomposed, and thus the engine was supplied with hydrogen gas instead of steam; at another time the heat was so feeble that steam of a very low power was obtained: and by reason of this inequality of heat, there was a corresponding inequality in the power produced from it. Major McCurdy, therefore, in (1826) improved his arrangement by making more heating chambers, as shown in plate X. fig. 5. He applied several cylindrical vessels made of wrought iron, with one end hemispherical and the other with a bonnet, which could be removed at pleasure. At A B C D E (plate X. fig. 5) is shown an end view of these chambers, in a cluster; all of them are connected (by means of pipes for water and steam) to each other, and to the steam chamber, F, above them. Mr. McCurdy says, he inserted or suspended in the centre of each of these vessels another vessel or tube of a still smaller size of similar materials, leaving a small space equal on all sides (varying according to their size, from half an inch to one inch and a half, which is thought sufficient for the generators of an engine of the largest size, between the outer and inner tubes or vessels. The inner tubes or vessels must be rendered steam-tight, and closed at both ends, except such a number as are intended as a reservoir to contain a body of steam for the supply of the engine; which number of interior tubes or vessels are left open or without a head, at the end opposite to where the steam and water enter, in their passage from the pump to the engine. These tubes or vessels thus arranged, which are termed duplex steam-generators, are placed in a common heated furnace, one above the other, in the most favourable position for heating, and are supplied with water by a forcing pump or pumps. The interior tube or vessel at the top, or nearest in connection with the engine, is the most suitable to be appropriated for the steam reservoir, and which should generally be made of about ten times the solid contents of the working cylinder of the engine. The outer or exterior tubes or vessels are connected by pipes leading from one to the other, through which the steam and water rush, from the time they are injected by the pumps till it passes into the steam reservoir, and from thence into the engine. To keep the interior tubes or vessels in their places, and at equal distances from the outer ones, spiral bands are put around them, extending the whole length of the inner tubes or vessels or rings, and used at intervals of from one to two feet apart. This plan was soon abandoned altogether.

Inventors seemed now to have received a new impulse. Their multifarious plans, good and bad, burst upon us in quick succession; some to make a noise and bustle for a time, and some merely to twinkle from their obscurity, and vanish without leaving even a remembrance behind. There were, however, two attempts made at the St. Katharine Docks, whilst they were in progress, which deserve notice. Mr. Jacob Perkins, in 1826, fitted up a boiler or generator, composed of numerous cast-iron hollow bars, placed horizontally, and united by vertical bars of a similar character; the interior size of the bars was about an inch and a half square. The metal was about one inch thick, and the length of these hollow bars was four feet. The fire was made below, and the flame passed through this faggot, imparting the heat to the water. A very short experience, with a small high-pressure engine adapted for pumping water, was sufficient to show the imperfection of this arrangement. The heat was irregularly generated, and the power was consequently irregular. The other attempt at St. Katharine's Docks was made by Dr. Alban, who, in order to obtain an equable temperature, used a bath of fusible metal, to which the fire was applied externally, and from which the heat was transmitted to the water internally. Plate X. fig. 6, shows three views of this arrangement; one is a side view of a compartment (of which there were one or more, according to the size of the engine). The side of the bath we have represented as broken away, so as to exhibit the pipes, a, a, a, which descend from the horizontal main. These vertical pipes, a, a, were kept full of water, and also more than half of the horizontal pipe, B, was kept supplied with water. They were surrounded by the bath case, C C, made of iron. This outer case, C C, held a quantity of fusible metal in the space between the water compartments, a, a, and B. Around C the fire, D, was arranged. The metal in C was fused, and imparted heat to the water. Fig. 2 shows an end view, stripped of the case, C, which will be seen represented by a dotted line. Fig. 3 shows an end view of the exterior casing, C. Dr. Alban certainly obtained a more regular temperature; but when the heat was applied too suddenly under the case, C, for the purpose of raising the steam in the mornings, the fusible metal expanded more rapidly at one place than at another; and, in several instances, broke the outer case.

Plate X. figs. 7, 8, and 9, are views of Mr. Walter Hancock's arrangement, for which he obtained a patent in the year 1827. The patentee's object was to combine safety, economy of fuel, and space, and to provide abundance of steam. Fig. 8 shows an *elevation* of this boiler, with part of the casing removed for the purpose of exhibiting the interior structure. A, one of the fire-doors, of which there were formerly two. B, the fire-place. D, the stoke-hole. E E, the chambers, constructed of the best wrought-iron. F F, the manner in which all the chambers are bolted together, so as to form a large boiler of many compartments. On the plan of the boiler, fig. 9, the fillets of iron, G G, are seen, which keep the individual compartments at a proper distance from each other. The spaces which these fillets leave are the flues of the boiler, through which the flame will be seen ascending, as at H. All these compartments are connected at the bottom, for the purpose of keeping the water in each at the proper level; and at the top, the steam is conveyed from each by as many pipes as there are chambers, into the steam feed-pipe, J, by which the steam is conveyed to the engines.

The only parts of this boiler which can be dreaded are the sides; but good ties will keep them together. And as to the bottom, end, and top of the boiler, which are composed of the edges of these compartments, if one part be burnt out or hurt, it is only that individual compartment which can burst, and its power of doing mischief is consequently limited.

The *chambers* are about two inches thick, and there is a space between each of two inches; there are ten, or more chambers, and there are, consequently, as many flues, and under the flues there is the requisite number of square feet for the fire. In the carriage called the "Infant," which Mr. Hancock described before the committee of the House of Commons (in 1831) the two cylinders of the engine were one foot stroke and nine inches diameter; and for these cylinders he had six square feet of fire, which is the dimension of the top and bottom of the boiler; the chambers are filled from half full to two-thirds with water, and the other third is left for steam; there is a communication quite through the series of chambers top and bottom; this communication is formed by means of two large bolts, which screw all the chambers together: the bottom one bolts the bottom part of the chambers, and the top one bolts the top part of the chambers; and by releasing those bolts at any time all the chambers fall apart, and by screwing them, they are all made tight again. The fire passes between the boxes; the sides of the boilers form the chimneys. "I have never gone (he continues) beyond 400lbs. pressure on an inch; I have worked it on a road at 400; the average pressure on an inch is from 60 to 100. Taking the average of roads, I work at about 70lbs. upon the square inch. At the present carriage I have 100 square feet of boiler exposed to the fire. These boilers are made of the best charcoal iron, about the eighth part of an inch thick. Such a boiler as this, is calculated to last twelve months or two years."

The size, number, and distance between the compartments, will, of course, always be regulated by the situation they are to be placed in, and the purpose they are intended for.

The object for constructing a boiler of numerous small compartments, is not only the reduction of weight by reason of holding less water, but, what is of more consequence, the safety of passengers and of the public in general. Mr. Hancock, in his evidence before the committee of the House of Commons, says, "The fault of many of the present boilers is, that if any accident happens there is a complete explosion. To construct a boiler wherein the danger is lessened, has been my object. I will give the committee an instance of its safety. I was travelling about nine miles an hour, at the time the boiler was about the twenty-fourth part of an inch thick,—I was working then at 100 lbs. on the square-inch, with thirteen persons on the present vehicle that I have now in use, and all of a sudden the carriage stopped, and for what reason I was at a loss to know. I got from my seat and went to the engineer to ask him what was the reason he had stopped the steam; he told me he had not stopped the carriage, and he immediately applied his hand to the gauge-cocks; I found there was neither steam nor water in the boiler. I immediately knew that the boiler was burst; they said they did not know it, as they heard no noise, and I told them that I did not mean they should know it. I said I would show them that it was so, and I took the boiler from the carriage and unscrewed it, and there were four large holes that I could put my hand into. This occurred from the chambers being too thin, and they drove all the water out of the boiler, and yet there was no injury to any person; there was not one person that heard any report: there was no steam, and there were no symptoms in any way that the machine itself had burst."

"In all the experience I have had with the working of these boilers, I have found that they never require cleaning. I consider that the ebullition is so rapid, and the action of water so violent, that it will not allow any dirt to fix." We shall discuss the safety of this boiler in our progress through the present Chapter.

Mr. Goldsworthy Gurney had, so early as 1829, publicly exhibited his improved boiler, which we shall shortly describe, but before doing so, it may be well to notice a modification of Hancock's boiler, for which Mr. Redman obtained a patent in 1833. To any one who examines the way in which the fillets of iron, G G, plate X., fig. 9, are placed to resist the lateral pressure of the steam in Hancock's boiler, it will be apparent, that although the tendency of the steam to bulge at the sides is completely prevented where the fillets, G G, are placed, those parts of the plate which were not propped by similar fillets might be stretched so as to belly out between the fillets. The plates at the sides of Mr. Hancock's chambers would then be fluted or corrugated. During some of my walks over Mr. Hancock's factory, I have seen old chambers furrowed in this manner. Mr. Hancock is now availing himself of this form, and in his last built carriage-boilers, the fillets have been disused. Plate X., fig. 10, shows an irregular section of Mr. Redman's boiler. A the fire-place, B B, &c. are the cylindrical flues up which the heated air ascends, imparting the necessary temperature to the water, C, which fills the interstices between the range of circular flues. Above the water, at D, will be seen the space reserved as steam-room. On the other side of the corrugated plate, D, there is a row of vertical cylindrical flues, and beyond these flues there is another film of water. Thus the water and the row of vertical flues are placed alternately, after the manner of Hancock's laminated boiler. To make the joints, round the edges of these corrugated plates, is a most difficult matter. The patentee has accommodated soft cast-iron pieces, into which the ends of the corrugated plates, top and bottom, are fastened by rivets. The ends are by this means closed, and the sides are rivetted together, and one chamber is formed.

Mr. James Fraser obtained a patent in 1833 for a very beautiful boiler (see plate X., fig. 11). Safety in this case seems to have formed no part of the patentee's scheme. Having been extensively engaged in the manufacture and use of boilers of large diameter, he has become habituated to them. The fire being made at A, the smoke, &c., was conveyed in the eccentric direction, B B, and imparted its heat to the water through which it passed. The view given is a cross section. C is the water, D the steam-room. The boiler being provided with man-hole, safety-valve, &c. &c. In order to prevent a collapse of the flues, the cross pipes exhibited in the drawing were introduced as props, they also furnished a passage for any steam formed in the adjoining compartments, to pass upwards.

Mr. Goldsworthy Gurney, a surgeon from Cornwall, and well known in the scientific world, has made the greatest step towards a light and safe boiler of any others who have yet appeared in the field. In the year 1825, he obtained a patent for a boiler and carriage. "To Mr. Gurney is due, and will be paid," says Dr. Lardner, "the honour of first proving the practicability and advantage of the project; and in the history of the adaptation of the locomotive engine to common roads, his name will stand before all others in point of time, and the success of his attempts will be recorded as the origin of the success of others in the same race." When water is heated it becomes specifically lighter than water at a lower temperature, the colder particles descend by their greater gravity, whilst the hotter particles ascend by their levity. This change of places must go on in all boilers; but Mr. Gurney availed himself of the law to construct a light and safe boiler entirely of tubes. We have seen that Mr. Griffith could not prevent the water from being driven out of the tubes of his boiler. Mr. Gurney determined, that whatever water was driven out before the steam generated in his tubes, should be driven upwards (to return again) and that its place should be supplied by an immediate ascent, from below, of colder water. His first apparatus was a glass tube, plate XI, fig. 1, bent round into a hoop shape, with a small opening above, at a, to allow the steam to blow off. The hoop was propped up on the table, b. On one side of this hoop he applied a spirit-lamp, e, and by some flocculent matter in the water, observed the current. The heated water ascended and colder water followed it up. The vapour, or steam, was allowed to blow off, at a, and the water descended in the other limb; a strong current was thus established, in the direction of the arrows, which prevented any part of the tube from being left dry to the action of the fire. He now proceeded to make this glass tube assume various elliptical shapes, and finding the current perfectly regular, he made the boiler exhibited in figs. 2 and 3, (plate XI). The same letters denote the same parts in both figures. When we look at fig. 3, we find the tubes twisted into the figure of an eight, and we can see how he still maintained his currents by means of the vertical pipe for the descent, A. The fire-doors are represented by the dotted lines. The fire was laid in the inside: whilst the hot particles of water ascended by the tubes, B B, C C,—the cold particles descended by A. The steam rose from the water in the separator, D, from whence it was conveyed to F. All the tubes were united to D and E. F was another separator, placed vertically; if any water were by accident blown up through the pipe, G, it descended into F, whilst the steam ascended to the upper part of this vertical separator, and was ready to be used by the engine. Mr. Gurney next fashioned the small pipes in the manner shown by figs. 4 and 5 (plate XI). On these two figures the same letters refer to the same parts. Fig. 4, is a longitudinal section from front to back along the middle of the fire. I I, are the horizontal pipes into which the small tubes are fastened by nuts upon the screwed ends of the small tubes. The currents are all established in the direction of the arrows. K K, are the vertical separators. Between, and connecting the vertical separators, K K, will be seen the breeches-piece, L; M is a safety-valve; N, the pipe, conveying the steam to the engine; O O, blow-cocks, whereby to ascertain the height of water in the boiler; P, the water supply-pipe, which, it will be seen, is coiled over the top of all the other tubes, and also above the fire; R, the iron chimney. Above all the tubes, which are immediately connected with the horizontal chambers, I I, and, resting close upon these tubes, Mr. Gurney has a plate of thin iron, over which the flame or heated gases are compelled to bend, so as to heat the coil, P. Before the heat passes up the chimney it has been farther reduced in temperature by its contact with the supply of cold water, which is forced into the boiler along P. The patentee used, sometimes, two or three similar coils of pipe to the same boiler, and by adopting a thin plate between each stratum of coil, he compelled the heat to wind round them. The thin plates of iron were not easily burnt out, because, resting upon a set of pipes, wherein a brisk current was maintained, the heat was immediately carried away. One plate lasted for three years of experiment. Each coil of pipe was weighed by the patentee, and he found that the weight carried exceeded the value of the heat saved, whenever more than one coil of pipe was used. The whole was cased in iron. Figures 6 and 7 (plate XI.) show Mr. Gurney's last arrangement. A, the point at which the water is pumped into the boiler; b, the water-level in the separator, E. It will be observed, that A B C D are all full of water. The fire is made at F, and plays around and through the tubes, C C. The hotter particles of water occasion a continuous flow from A a, through C, to D. When they arrive at D, their colder particles descend through B, and again are drawn through the tubes, C. The tubes, C, by their inclination, always offer an ascent for the hotter particles and for the steam. By this arrangement, the circulation is constant and complete. The steam is rapidly given off in E, where it is ready for the engine. This chamber, E, is sometimes placed vertically, as in his former boilers, (fig. 4) instead of being placed horizontally. Sometimes there are two of these steam-chambers, E, connected together, and to the engine, by what is termed a breeches-piece. G (fig. 7) is the fire-door, H the flue. Q is a pipe which descends to the larger pipe, A, and by it the water blown up into E, is returned to be boiled.

In his evidence before the committee of the House of

Commons, Mr. Gurney stated, that, in the first instance, the tubes of which his boiler was composed were not welded, but simply "butted" together; the consequence was, that whenever any great pressure came upon them the seam opened; but, from practice and experience, he found it necessary to wrap over, or over-lap the edges, and weld them from end to end; and now they are not subject to those accidents. The diameter of the tubes was from half an inch to two inches; he recommended an inch diameter. They were proved to about 800 lbs., but might bear 2000 lbs; he has never been able to burst one when well made, and lapped and welded. The average pressure on the boiler, per square inch, in his ordinary rate of travelling, is about 70 lbs. Sometimes he may work up to 100 lbs. and 120 lbs.; but that is a case of great emergency; never more than 130 lbs. The thickness of the iron tubes is about the eighth of an inch."

Upon the comparative merits of these boilers of Mr. Hancock and Mr. Gurney, Mr. Farey says, in his evidence before the committee of the House of Commons, 1831, "There have been, for several years past, a number of locomotive-engines in constant use on rail-ways, all of them having large high-pressure boilers, very much more dangerous than Mr. Gurney's or Mr. Hancock's, whether we consider the probability of explosion, or the consequences likely to follow an explosion, because being of large diameters they are less capable of sustaining the internal pressure of the steam, and also they contain a large stock of confined steam and hot water. The instances of explosion among those locomotive-engines have however been very rare indeed."

"If Mr. Hancock's boiler were to explode, it is understood that there would be no danger at all?"—"It is very difficult to foresee that; at the same time the risk of explosion in Mr. Hancock's boiler is certainly very much less than in the locomotive boilers which are in constant use on a large scale on rail-ways.

"The metal plates of which the boiler is composed will burn through by the continuance of the action of the fire, and may crack or open so as to let the steam or water out of the boiler and disable the coach from proceeding, but that is hardly to be called an explosion; no one would be hurt; the crack which lets out the hot water is sure to throw it into the fire in that case, and not on the passengers."

"You consider the danger to passengers by the chance of bursting of a boiler, as not equivalent to the danger of horses running away?"—"It is not equivalent in my opinion: the probability of a coach being overturned by the horses is far greater than that of a boiler bursting, and when either accident does occur, the probable extent of mischief from an overturn, in which all the passengers must participate, is much greater than could be expected from the bursting of a boiler, which must always be kept at a considerable distance from the passengers, on account of the heat."

"In Mr. Gurney's boiler (Mr. Farey continues) I think the subdivision of the water into small spaces is carried too far, because the steam cannot get freely away out of such small tubes as he uses (and they are also of great length) without displacing much of water which ought always to be contained within them. By an ingenious arrangement of connecting pipes and vessels which he called separators, he collects all the water which is so displaced along with the steam, and returns it again into the lower ends of the same tubes, and thus avoids the evil of water boiling over into the engines; but that makes only a partial remedy for the diminished production of steam, which is attendant on the absence of the water from the heated tubes, and the still greater mischief of burning and destroying the metal. Hence the evil of burning out the tubes is very great. Also his separators hold a considerable weight of water, from which no steam is generated; and they require to be heavy in metal, to render them quite safe and strong. Mr. Hancock has taken the middle course in subdividing the water in his boiler, having all that can be required for safety*, and the weight, I believe, on the whole, to be less than that of any other boiler which will produce the same power of steam; for, owing to the freedom with which the steam can get away in bubbles without carrying water with it, the surface of the heated metal is never left without liquid. Hence a greater effect of boiling is attained from a given surface of metal and body of contained water, and that with a much greater durability of the metal plates than I think will ever be obtained with small tubes."

"The danger of explosion I hold to be very slight; the metal of Mr. Hancock's chambers will burn through in time, the same as that of Mr. Gurney's tubes, but not so soon; I think, taking the thickness of metal to be the same in both cases, no injury will be done by such burning through. The flat chambers in Mr. Hancock's boiler are very judiciously combined, and are secured against bursting by causing the pressure which tends to burst each one open to be counteracted by the corresponding pressure of the neighbouring chamber; and the outside chambers are secured by six bolts of prodigious strength, which pass through all the chambers, and unite them all together so firmly that I see no probability of an explosion. Mr. Gurney's vessels, called separators, are generally secured by hoops round them."

Mr. William Crawshay of Cyfaithfa iron works, in a letter to Sir Charles Dance, dated 23rd February, 1832,

* Or was thought so in 1831, from all the facts *then* known. This comparison of the two boilers I shall touch upon hereafter.

says, "The favourable opinion entertained by my engineer and myself of the tubular boiler (Mr. Gurney's), over every other we have yet seen, not only remains unshaken, but is strengthened and confirmed by eighteen months' constant use, and observation of it on our own road; and also by all we can collect from other testimony, of what is doing elsewhere in this neighbourhood with boilers of other descriptions. The ease and economy of first construction; the facility of repair when required; the extreme lightness; the great capacity for raising steam; and the perfect freedom from danger of the tubular boiler, all render it, in our opinions, pre-eminently adapted to locomotive-engines; and I hope in the course of a few months to apply it to engines and carriages suited to rail-roads and heavy work so successfully, as to render the advantage of steam-power over that of horses still greater than it now is. As, however, facts of past performances of any kind are more satisfactory than anticipations of the future, I beg to state to you, that in the past twelve months, between the 1st day of January, 1831, and the 1st day of January, 1832, the locomotive-engine which I bought of Mr. Gurney, weighing only thirty-five hundred weight, including every thing whatever belonging to it, with water and fuel in a working state, conveyed 42,300 tons of coal, iron-stone, and iron, exclusive of the carriages on which they were drawn, the distance of two miles and a half upon our rail-road at Hirwain, in journeys of from twenty to thirty tons, as suited our convenience; during which time, the entire consumption of coal was 299 tons, which at 3*s.* per ton amounts to 44*l.* 17*s.* The wages of the engineer 52*l.*, and those of the boy 15*l.* 12*s.*; together, exclusive of the trifling repair of the engine, and the oil and other little matters required for its use, 112*l.* 9*s.*, or less than one farthing per ton per mile, for the goods conveyed; and I must not omit to observe to you, that had there been nearly double the work to do on this road, the engine would have done it with little or no increased expense, as she was invariably working idle, for the purpose of keeping the boiler full, about one-half of her time."

In the boiler shown at fig. 6, the same arrangement of a coil and plate (above described, page 142) was used; and as considerable heat would still be driven up the chimney, after passing the cold water coil, he availed himself of this waste heat to destroy the steam, which the engines puffed off at each stroke (see pages 19 and 37); thus preventing those clouds of vapour which would otherwise have been created by every alternation of the pistons. By injecting the waste steam into the chimney, he at once decomposed it, and the permanently elastic vapour produced was invisible. The value of this steam injection was of still farther importance; it created a current upwards (see page 64), and saved the necessity of a tall chimney. In the year 1830, at Paris, a gentleman working under Mr. Gurney's patent, attempted to use this boiler without the separators, but the plan was abandoned on account of the imperfect separation of the steam from the water.

Sir James Anderson and Mr. James made many experiments with a boiler, of which the following is an account, transcribed from the Mechanics' Magazine :—

"They formed the boiler by combining a series of annular tubes or ring-formed chambers, which chambers communicate with each other by apertures running through the whole series, in order to allow the water and the steam to flow freely from end to end of the cylindrical vessel, so formed by the combined tubes or chambers; and which vessel has a furnace adapted within it for the purpose of heating the water and the steam contained in the annular tubes or chambers. That is to say, (to speak more plainly), a series of hollow rings or annular tubes, (made, we understand, of the best iron, and three-fourths of an inch in diameter), each communicating with the other, are arranged spiral-wise and circularly, so as to form a cylinder of rings; and within this cylinder a furnace is inserted upon suitable bearings, and capable of sliding in and out, which, with its flue, occupies the whole interior of the cylinder. The rings or tubes form a continuous length of 430 feet 5 inches. They are filled with water rather more than half way up. The flame and heated vapour arising from the furnace, in passing from thence to the chimney, enter the jacket, (or outer casing of the cylinder of rings), and embrace the external surface of the tubes.—By these means the water in the lower parts of the vessel (or lower portion of the tubing) is made to boil, and the steam generating therefrom, rising into the upper, becomes greatly increased in its elastic force by the immediate action of the fire. The steam is kept confined in this upper portion of the tubing till the pressure reaches any desired point, when it is let off by an eduction-pipe into the working cylinder."

In 1833, a patent was obtained by Sir Charles Dance and Mr. Field for an arrangement of tubes, plate XI., fig. 10, which was considered superior to Gurney's. The bent pipes of Gurney's boiler will be discovered upon reference to the plate; and the whole will be found to consist of two of Gurney's boilers (but without the separators, F, fig. 2, K K, fig. 5, and E, fig. 6), backed into each other. The coil-pipe, J, is here used, conveying the cold (or rather the cooler) water from the tank to E, from whence it rises to C, becoming heated in its passage upwards. Water pumped into D also ascends to B, in the same manner; and at B and C the steam, from the two distinct boilers, E, C, and D B, rises up to F and G, and is drawn off to the engines, whilst the cooler particles descend in the vertical pipes below C and B, to pass again over the fire with other water going in the upward direction.

The late Mr. Trevethick described to the committee of the House of Commons a plan he had in view for constructing a safe boiler and a good condenser, in the following words :—" I have made an entire new engine, both in principle and arrangements; the fire-place, boiler, and condenser, are formed of six wrought-iron tubes, standing perpendicular on their ends, encircled the one within the other for the purpose of safety, and to occupy little room, also for keeping the boiler to one constant gauge, with fine distilled water, permanently working without loss, by condensing the steam and never suffering it to escape out of the engine, but returning it from the condenser back again into the boiler every stroke of the engine by a force-pump, and where an engine is perfectly tight it would work for ever without a replenish of water; but to supply leaks, a small evaporating apparatus is used for supplying the deficiency with distilled water, which effectually prevents any fluctuation in the height of water in the boiler or collection of sediment, and it is impossible ever to get the boiler red hot, there being no space for the water to fly to, out of the boiler but into the condenser; and this is so small, that if by any means the force-pump did not return the water regularly from the condenser to the boiler, the space in the condenser, by taking one inch in depth of water out of the boiler, would fill and glut the condenser so, that the engine would stand still, and, as the water cannot diminish, it does not require a large quantity of water, or water space in the boiler, so necessary in other engines, to guard against fluctuation in the feed, and prevent the boiler becoming red hot. The boiler being considerably less, the strength and room will be increased, and, never getting hot, the engine might be worked with much higher steam. My engine to be one hundred horse-power, to raise sufficient steam, the fire-tube must be three feet diameter, which would give the boiler a diameter of three feet eight inches, and that a half-inch thick, according to the theory of the strength of iron, would sustain a pressure of 1,736 pounds to the inch, which is four times as great as the gas-holders are charged with, and thirty-two times the pressure that the high-pressure engines work with at present, which is still farther proof that the explosions have been solely occasioned by the boilers being under water gauge, and heated red hot. If after boilers have been forced on their trial by a cold-water pressure, to stand ten times the pressure that they are to be worked at, and a boiler should happen to explode, the shock would be first received by the next surrounding tube, and so on for six successive surrounding tubes; each space between the tubes would admit the steam to escape gently up the chimney without harm, and the outside tube that encircles the whole might be made of three-quarters of an inch thick, so that it would put injury from explosion beyond possibility."

The death of Mr. Trevethick has prevented the complete trial of this his last boiler; and, although no boiler of value may result from his description, given above, it contains what is worthy of his name—a name as inseparably connected with high-pressure steam and locomotion, as that of James Watt with the condensing engine and rotary movement.

Mr. Porter and Mr. Beale have proposed a bath of spirits of turpentine or other volatile oil, through which to transmit heat to water, for raising steam and other vapours.

Dr. Ure has proposed a bath, the intermediate liquid being chloride of calcium, which he kept at a uniform temperature, by means of his heat regulator or thermostat, hereafter described. Such a bath has not yet been applied to the purpose of generating steam; but in an experimental sugar-house, the property of Government, Dr. Ure has applied his bath with great success.

In 1831, Mr. Galy Cazalat, formerly of the School of Arts, now professor of mathematical and physical science at the Royal College of Versailles, took out a patent for (amongst other things) improvements in boilers: he recommends a self-regulating mode of abstracting heat from a boiler, in the event of the steam rising too high in temperature or pressure. Certain parts of his boiler are immersed in a bath (saturated solution of potash) which boils at 284° (Far.), and the patentee's object is to prevent even the evaporation of this bath; but when it does evaporate, the superabundant heat of the steam is likewise carried off.

In 1833 the same ingenious gentleman obtained another patent. This patent was taken out in the name of Alexander Gordon*, the former in the name of Mr. Berry. This patent of 1833 not having yet been introduced, we shall not here describe the arrangements; the specification can be seen at the Inrolment-office.

On plate XI., fig. 8, is an elevation of the boiler used by Mr. Ogle and Mr. Summers, for which they obtained a patent. Fig. 9 is a plan of the same. The smoke and heated air from the fire ascend past the sides and through the interior flue of the vertical cylinders, B B. By means of these vertical cylinders, with flues up through the interior, the water is divided into films, whilst the form best calculated to resist pressure is maintained. Mr. Ogle, in his evidence before the committee of the House of Com-

* When a foreigner has published his invention abroad, it is necessary to have the English patent in another name than his own. Mr. Galy Cazalat is a personal friend, and although I am no ways liable for the success or otherwise of his invention, I cannot but regard the arrangement as highly philosophical.—A. G.

mons (1831), says—"The base of the boiler and the summit are composed of cross-pieces, cylindrical within, and square without; there are holes bored through these cross-pieces, and inserted through the whole is an air-tube. The inner hole of the lower surface, and the under hole of the upper surface, are rather larger than the other ones. Round the air-tube is placed a small cylinder, the collar of which fits round the larger aperture on the inner surface of the lower frame, and the under surface of the upper framework. These are both drawn together by screws from the top; these cross-pieces are united by connecting pieces, the whole strongly bolted together, so that we obtain in one-tenth of the space, and with one-tenth of the weight, the same heating surface and power as are now obtained in other and low-pressure boilers, with incalculably greater safety. Our present experimental boiler contains 250 superficial feet of heating surface in the space of three feet eight inches high, three feet long, and two feet four inches broad, and weighs about 800 weight."

Messrs. Braithwaite and Erricsson made a boiler similar to fig. 1, (plate XII.), and adapted it to a locomotive carriage upon the Liverpool and Manchester railway. The engine was rejected by the directors of that company, for non-compliance with their published requirements; but boilers of the same construction have been since then made to a considerable extent by Mr. Braithwaite.

In 1833, Mr. Thomas Howard, of the King and Queen iron-works, obtained a patent for a steam-engine ("patent vapour engine"), of which the boiler may be described as follows, in Mr. Howard's words:—"The heat from a coke fire is conveyed to the surface on which the vaporisation is performed, through the medium of such quantity of mercury as will render the varying intensity of the fire, &c. sufficiently manageable: its temperature being indicated by a thermometer, which, when water is employed, should not be much lower than 400° Farenheit, but may be allowed to fluctuate between that and 500°, without perceptibly affecting the power of the engine. The surface exposed to the fire, in the engine of ten horses' power now at work, is the bottom of a shallow wrought-iron pan, containing the mercury, and presenting to the fire seven square feet, or three-fourths of a square foot per horse power. It is placed beneath the working cylinder, which is twenty inches diameter. Above the mercury is a very thin covering of iron, so contrived as to present about four times the fire surface, and is throughout in close contact with the mercury beneath. The vaporisation is effected by dispersing upon the latter surface, at intervals, (say each stroke of the piston) through a nozzle adapted to the purpose, the required small quantity of water, alcohol, or other liquid, previously heated to about its boiling point, which is instantly and completely vaporised. The quantity of liquid injected, on which the power of the engine is dependent, is regulated by the movement of a small valve, adjusted either by hand or by a governor.

"The fire is supplied by a blowing machine with air, which passes through a regulating valve, and is so admitted to the fuel as to act uniformly on it. A chamber surrounds the working cylinder, into which the vapour passes, previously to its entering the latter by the induction valves. The heat from the fuel, that has not been absorbed by the mercury, passes, prior to reaching the flue, through a casing enclosing the chamber, by means of which the vapour within the latter is heated, say to about 400°: at the same time the pressure is in general only twenty or twenty-five pounds per inch, including that of the atmosphere. Thus, instead of the considerable loss of effect from condensation which takes place in the steam-engine, an additional expansion is given to the vapour after its formation, to the extent of nearly one-half; that is, (says the inventor) one volume of steam at 212° becomes one and a half at 450°."

His Majesty's steam-ship the "Comet" is now having Mr. Howard's invention applied, and to that large experiment we look with interest.

The boilers in use upon the Liverpool and Manchester railway are said to be the joint invention of Mr. Henry Booth, treasurer, and Mr. George Stephenson, engineer, to that company. The invention not being the subject of a patent, has been extensively copied, and introduced, with sundry alterations, upon railroads in England, Scotland, and the United States of America. Figs. 2 and 3 (plate XII.) will illustrate their construction; A, the fire-place; B, the water; D, the steam-room. The fire is made in a double fire-place, into the duplex portion of which water was admitted, and by this arrangement loss of heat by radiation is lessened. At the back of the fire will be seen a plate, from which proceed a number of horizontal flue-tubes, c c. The heated gases ascend from the fire, and then travel through these small flues, which are always surrounded by water. The small horizontal flues terminate in the vertical chimney, at the bottom of which a provision is made for collecting and extinguishing any hot cinders that may have, by the intensity of the draft up the chimney, been drawn through. The number of these flue-tubes vary from 25 to 150 in different engines. Mr. Stephenson's "Arrow" had a heating surface of furnace and flues equal to 165 square feet; his "Meteor" had 159 square feet of heating surface; the "Rocket" had 25 flue-tubes, and the "Northumbrian" (see plate VII.) had 150, each 1½ inch diameter, passing along the boiler through the water from end to end. The fuel required to evaporate a cubic foot of water in these boilers is about 10 lbs. weight of coke.

Mr. Dodd, engineer to the Monkland and Kirkentilloch railway (Scotland), has introduced this species of boiler on that railway. He employs copper tubes, 60 in number, for an engine drawing 60 tons gross weight five miles per hour. (See page 60.)

Mr. Perkins' patent improvements to boilers consist of a lining, A B, placed within the boiler, as shown on figs. 7 and 8 (plate XII.) Fig. 7 is a long vertical boiler or caldron, or it may represent the limb of a close high-pressure boiler. The lining, A, is similar in shape to the boiler, but shorter and of smaller diameter than the outer case. The lining has a hole at the bottom, and by this means the heated particles of water ascend between the outer case and the lining, being the hottest part, then curl over and descend, after parting with their steam at the top. The currents being established, as shown by the arrows in figs. 7 and 8 (plate XII.) up the sides, down the middle, and through a hole at the bottom of the lining, to be farther heated and sent upwards as before. This principle has been applied to boilers on the Liverpool and Manchester railway with success, as it would appear from the transactions which I minuted of the Institution of Civil Engineers. "The recent improvements proposed for boilers by Mr. Perkins were shortly stated by a member. He had seen the state of flue-tubes used in the Liverpool and Manchester locomotives, both before and after a run of 3,000 or 4,000 miles. Whilst the destructive chemical and mechanical effects on the interior of these flues were manifest in every tube, before the side lining was introduced by Mr. Perkins, flue-tubes with Mr. Perkins' lining between them and the sides of the boiler, had travelled the same distance with very little deterioration, and that only a mechanical deterioration. Flue-tubes taken out of a boiler which had not the lining, after the work of 3,000 miles, were often worn so thin as to collapse and burst, or if they did not collapse, were often worn very thin,—at least half of the substance being worn away in the interior of the pipes. The action of the heat and the grinding of cinders, as they pass along these copper tubes, by the intensity of the blast, often reduce the tubes to the thickness of paper."

"Other members were of opinion that the crowded state of these flue-tubes prevented the circulation, and globules of steam being formed could not get away, but clung to the tubes, and thus, by the *non-conducting* steam being on one side of the metal of the tube, whilst an intensity of heat impinged on the other, the burning of the tube was a necessary consequence. Some members maintained that if the outer rows of tubes had been removed, a brisker circulation might have been obtained without using Mr. Perkins's lining, and that this quicker circulation would have kept the water nearer the tubes, to conduct off the heat."

It is worthy of remark, that upon the Monkland and Kirkentilloch railway, where the speed at which the locomotives travel is not above five or six miles an hour, the flue-tubes have not been removed for two years.

Mr. Joseph Gibbs obtained a patent (in 1831) for a boiler, with descending flue. Fig. 4 (plate XII.) is a vertical section of it. The fire-place was $1\frac{1}{2}$ foot diameter at the well, or lower portion; and the extreme height was $5\frac{1}{2}$ feet. Within a foot and a half of the top, the fire was made; the flue descends spirally through the water, below the fire-place, and is said to be at its extreme end as cold as 100° (of Far.) With this boiler he has, in his experiments, evaporated 80 gallons of water in one hour, with 80 lbs. of coke. I do not find that a boiler of this description is any where in use.

Mr. Gibbs more recently engaged in experiments with another boiler, which will be understood in reference to fig. 6, plate XII, which exhibits *part* of a boiler. A A A are conical chambers, into which the water, B, flows. These chambers are made to project into the furnace and flues, so as to obtain an increased heating surface.

Mr. Smith, of Princes Street, Leicester Square, has recently employed an arrangement somewhat similar to this last, in a boiler, with this difference, that the apex of the cones were placed downwards, and side linings, similar to figs. 7 and 8, plate XII., were introduced to promote circulation.

Dr. Church, of Birmingham, has tried the boiler, of which a portion is shown at fig. 5, plate XII. The flue, in which the arrows are seen ascending and descending is an inverted syphon, and the water-spaces surround the flue. But all the water compartments are connected with each other at the bottom, and open upwards into a large chamber at the top, from whence the steam is conveyed to the engines.

A patent has been obtained by Mr. Collier, of whose boiler figs. 9 and 10, plate XII. are views. The whole furnace-place is surrounded by water. From the front, and attached thereto, are several flat chambers, round, and up through which, the fire plays. On fig. 9, a horizontal plate will be seen in the chamber, for the purpose of making the current take the direction indicated by the arrows. By an experiment made at Mr. Brunton's chain cable factory, with one of these boilers, the saving is reported and believed to be as 8 to 13, when compared with the boiler which formerly did the same work.

In 1833, Mr. George H. Palmer obtained a patent for improvements in boilers and apparatus connected therewith, which he intends for locomotive purposes. His object seems to have been to obtain a means for regulating the combustion of fuel exactly, and thereby to ensure the generation of the requisite quantity of steam, and no more: this he accomplishes by a self-regulating blast. In connexion with this, he has a self-adjusting apparatus, which opens the safety-valve, and relieves the pressure, when the self-regulating blast fails in its instant operation. This safety-valve is only a secondary mode of insuring security to the boiler, under circumstances which the patentee does not anticipate. Mr. Palmer also provides a self-acting safety apparatus, so that whenever by accident, or otherwise, the water in the boiler is reduced below the proper water-line the process of combustion in the furnace may be suspended, and the boiler be thus prevented from injury. There is moreover provided a means for making the products of combustion evolved from the furnace, escape into the atmosphere below the level of the furnace-bars, with the view of preventing the admission of atmospheric air into the furnace, excepting what is forced in from the blower; so that when atmospheric air is not purposely blown or drawn through the fire to promote combustion, there is no supporter of combustion present, and the fire is immediately and effectually damped. On plate XIII., fig. 1, is a transverse section of this boiler furnace and calorific regulator, showing its connection with the blast regulator. A is the boiler, B the furnace, D is an iron frame, which supports the grate, C. A provision being made for expeditiously removing the grate when requisite. The fuel is added through the hopper. E E are two (of four) flue pipes, to convey the carbonic acid and other gases down below the level of the ash-pit. This transverse section does not admit of two circulating tubes being shown, but there are two or more such tubes used to convey water downwards outside of the boiler, from above the furnace to the annular space at the bottom of the furnace. K is a pipe through which the atmospheric air is injected into the casing, L, which surrounds the ash-pit. From this casing the air is, by means of small holes, diffused in its action on the fuel in the furnace. To one extremity of the pipe, K, is attached a regulating valve or cover, by regulating which with the hand, the quantity of air for the furnace is controlled. "To the other extremity of the pipe, K, is adapted a hinged valve or cover, N, so weighted as to counterpoise the pressure of the air within; the pipe when closed compels the air discharged by the blowing apparatus to pass into the casing, L, and from thence into the furnace through the flue pipes, E E, &c. into the atmosphere, excepting that quantity which may be discharged through the valve N. The use of this valve is to limit the temperature of the water, and consequently the pressure of the steam in the boiler, by permitting, when open, the discharge of a great portion of the atmospheric air, otherwise required for combustion. To effect this object the valve, N, is connected by levers, O P Q, with their necessary rods of communication to the calorific regulating apparatus R, which consists of a piston, of sufficient area to overcome the resistance opposed to it, working through a stuffing box in a cylindrical syphon tube, containing a quantity of mercury as a medium, by which the steam passing from the boiler into the regulating chamber acts upon the aforesaid piston. There is a safety valve, with its graduated lever and weight; and a loop is formed on the end of the lever, and embraces the screwed end of the regulator piston. When the nut, V, comes in contact with the loop, the lever and safety valve are lifted effectually, preventing the occurrence of accidents should the safety valve remain closed beyond the limiting pressure. The action of the safety valve and lever is rendered simultaneous by two small connecting links. X is a chamber attached to the crown of the furnace, and connected by a tube, Y, with a piston and cylinder of precisely the same description and construction as that used for the calorific regulator R, and may be placed in any convenient situation for operating on a safety slide cock or valve, Z, which, when the water in the boiler has evaporated so low as to endanger its safety from a deficiency of supply from the force pump, is closed, and completely prevents the passage of atmospheric air into the furnace; thus combustion instantly ceases, the ignited fuel being deprived of air. The motion communicated to the piston by the steam generated in the chamber, X, operates on the lever, 1, by the cam 2, the lever rising with the piston until the cam or detent passes the fin 3, when the slide, Z, is instantaneously released, and falls by its own gravity, completely closing the passage through the pipe, K. The combustion being suspended, the temperature of the water, and consequently the pressure of the steam, is instantly reduced, thus preventing the destruction of the boiler by the powerful action of the fuel when the heating surface is unprotected by the water. For facilitating the reference, the regulators, R, are arranged with a view to perspicuity, rather than mechanical exactness."

Mr. Joseph Maudsley's patent boiler (1833) consists of several concentric hollow cylinders of water, between which the flues from the fire are made to pass. In external appearance it is not unlike Mr. Stephenson's last boiler (plate VII.), with the exception that, instead of having small flue tubes passing through the water, the horizontal flues and horizontal water-spaces are concentric chambers, having but one centre. There is an annular space of water, and an annular space of flue, alternately. These horizontal hollow cylinders of water are, at one place, surmounted by a vertical chamber, into which all the steam generated is collected, and from which it is led off in the usual manner to the engines.

Mr. Squire and Colonel Macerone (plate VIII. fig. 3) have constructed their patent boiler as exhibited at fig. 3 (plate XIII.) The vertical chambers shown in this elevation are about two-thirds filled with water. They are 3 or 3½ inches diameter; the outer rows nearly four feet long, the inner ones, under which the fire is made, three feet long. They are all united near the top, and near the bottom, as shown in the plate. Eighty-one of these vertical tubes are used for their carriage (described page 113). The steam ascends to the steam feed-pipe, from the top of the respective tubes, by the smaller pipes.

Mr. Douglas, of New York, has lately proposed, in his specification of a patent for furnaces, (1834,) the application of conductors of heat, similar to figures 15 and 16, plate (XIII.) The figures are shown in perspective, and are intended to represent plates of metal closely fitted to a square or round flue, which plates of metal, by their conducting powers, convey the heat in amongst the liquid to be boiled. By this means a considerable surface may be obtained in a very small space. The patentee sometimes uses " vertical tubes or prisms or plates in clusters, attached to the bottoms of boilers or vessels containing any kind of liquid, or attached to the flues or tubes." The experiments already made with such apparatus are in the highest degree satisfactory.

The anticipated extension of elemental power for locomotive purposes requires that some comparison of the above boilers be made, wherein the durability and safety may be seen.

It has been stated above, that if water be not kept in contact with the metal through which heat is transmitted, destruction of such metal must be the consequence. There are some engineers who think it is sufficient that steam be in contact with the metal. This, however, is contrary to the well-known laws of nature, for steam is a bad conductor of heat *, and consequently there can be no sufficiently rapid removal of heat from the metal. Water

* Although it be a good *carrier* of heat.

is a good conductor of heat, for the purpose of saving boilers in most of their shapes. It will, however, not be found so in every arrangement of boilers, because water will not convey heat downwards. For instance, water may be in a state of ebullition (212°) at the top of such a boiler as plate XII., fig. 4, whilst at the lower extremity of the same boiler the temperature may not be above 100 degrees; and, with a chamber a little deeper than this, ice might remain unmelted by any heat which could be applied at the top. Such an arrangement may be good for saving fuel, because the descending chimney brings the heat therein into contact with a colder body; but the good is more than counterbalanced by a liability to burn out the upper portion of the boiler.

Steam must then never be allowed to remain in contact with metal against which fire impinges: a way must be provided for it to escape from such a position; a difficulty which presents itself in all the small chamber, or tubular boilers, described in the foregoing pages: in some of them constantly, in others when the pumps do not perform their regular duty.

In all boilers there will be found, after a time, upon the bottom and sides, two kinds of deposit; one is of such foreign matter as has been mechanically suspended in the water and now thrown down; the other, known by the name of fur, is a hard substance, requiring to be chipped off by hammer and chisel. The former may be prevented by filtration of the water before it enters the boiler, the latter, being chemically suspended in the water, cannot be precipitated by any means yet known, without the agency of heat; it is cleaned out always with difficulty, and, being a non-conductor, if not cleaned out, the heat from the fire-place and flues is not transmitted to the water with sufficient rapidity; hence a deterioration of the boiler. A remarkable instance was mentioned by Mr. Thorold, to the Institution of Civil Engineers, of two boilers constructed at the same time and of similar material. The cross section of one was a circle, plate XII., fig. 11. The cross section of the other was of a crescent shape, plate XII., fig. 12, with the horns downwards. In the cavities of the horns, or legs, of the latter, which rested on the brickwork of the furnace, the fur and mud collected so readily that the water could not carry off the heat from the fire with sufficient rapidity. These legs of the crescent-shaped boiler consequently became red-hot, and in *three weeks* the boiler was useless; whilst the boiler first mentioned, whose cross section was completely circular, had worked for *nine years and a half* without repair, and the engine during that time was uninterrupted in its working, except for the purpose of cleaning. It is an error to suppose that the deposit can be blown off with the water like so much muddy water: so much of it as is composed of mud may be got rid of, by blowing off, but the chemical deposit of fur requires to be chipped off. The owners of small chamber boilers have got rid of this fur partially, in consequence of another evil; the boiler, when *red hot*, casts scales of fur, which are blown out sometimes with the mud. But such a remedy is as bad as the disease. It will be seen that Mr. Gurney, by removing the plugs, plate XI., fig. 6, at the corners of his tubes, can chip and rake out the fur. The plugs on the tubes, and the flaunches on the larger chambers, giving the most perfect facility for so doing.

Pans, for collecting the concrete formation and also any particles of mud, mechanically suspended in the water, are now more and more generally used. These pans are fourteen inches in diameter, and four or eight inches deep (tripods). The water in them being kept from circulation, soon deposits a little fur; and on this, as a nucleus, the concrete deposited by the water is formed, whilst the mud, &c., in mere mechanical suspension, is thrown into ceeds from an uncontrolled increase of power, pressing outwards, and overcoming the resistance offered by the metal of which the boiler is made. I believe explosions are of two kinds, *simple* and *electric*. That is to say, by a regular increase of pressure, which can be prevented by an ordinary safety-valve, and by a sudden shock, which no safety-valve yet devised can prevent.

The explosion of Hill and Burstall's boiler was of the former kind. The fire had been urged, and the safety-valve had been overloaded at the same time. Steam was seen to escape from the joints of the plates and from the rivet holes; rivet was seen to break after rivet, and in half a minute's time thereafter an explosion took place. The accident to a marine engine boiler which called for and engaged the attention of Parliament ten years ago, was of a similar nature, although no warning was given as in the last case. These, and numerous others mentioned by M. Arago, might in all probability have been prevented by a large safety-valve in good order.

Engineers, contemplating accident from no other than pressure gradually increasing, have relied almost entirely upon safety-valves which would open when the pressure became too high, and let the superabundant power blow off.

On plate XIII. some of these safety-valves are shown.

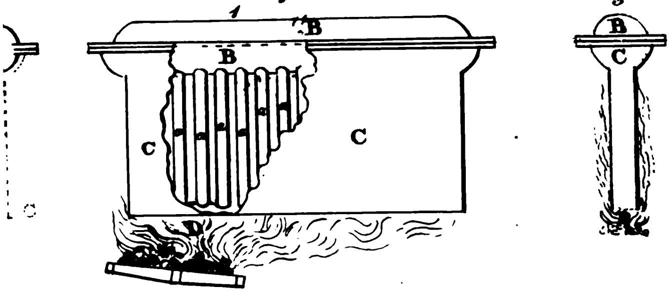
Fig. 8. *a a*, is the top of a boiler, *b* a conical valve which is kept close by a lever, *c*, resting upon it, which lever is adjusted by a sliding weight, *d*. The pressure increasing from within presses *b* open, and the surplus steam escapes.

Fig. 9 is a similar valve, but adapted for locomotion by being adjusted with a spiral spring of a regulated power. The spring not being affected by jolts, as a weight would be.

Fig. 10. Another valve for locomotive carriages, having a bent flat spring, *f*, which can be adjusted to greater or less pressure by the thumb-screw, *e*.

Plate 10.

Fig: 6.



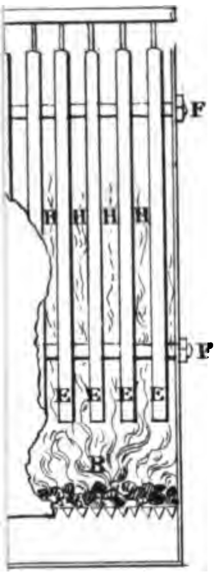
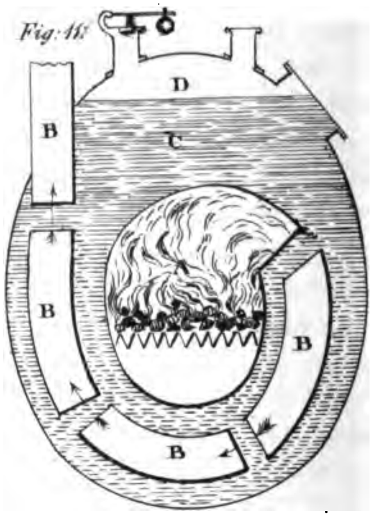


Fig: 11.



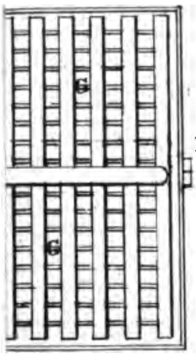


Fig: 10.

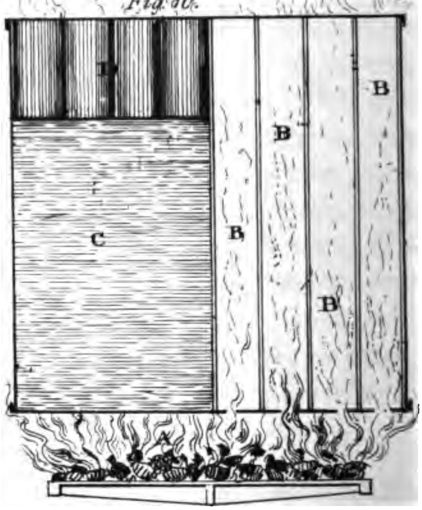


Fig. 11 exhibits a well-turned spherical ball, *g*, resting on the valve-seat at the top of the pipe, *h*. As the steam blows past *g*, it escapes by the pipe *k*, *g* being retained near the seat by a dome.

Fig. 12 exhibits the arrangement required by law in France. *l* is the top of the boiler; the superabundant steam passes off by the branch pipe, *m m*, and lifts the valve, *o*, which is weighted in the usual manner. Lest this valve, *o*, should not lift before the steam arrives at a pressure which would endanger the boiler, a safety-plate, *p p*, made of zinc, tin, and bismuth, is provided, and held in its position by an iron grating above it. This plate, *p p*, is fusible at a low temperature, and before the pressure of steam can have increased to a dangerous extent, the heat necessary for its increase will have melted the safety-plate, and allowed the steam to blow through the grating.

Mr. Gurney has proposed to effect the same end by means of one or more fusible plugs.

Fig. 13 is a combination whereby the increased temperature may be made to check the safety valve. On fig. 13 the usual arrangement of a valve with weighted lever is seen; and in the interior of the boiler is fixed one of Dr. Ure's thermostats, in shape like a coach-spring; the upper and under limbs of which recede from each other by an increase of temperature, and approach each other again when the temperature decreases. This ingenious instrument, the thermostat, is constructed of two metals, which expand at different degrees of temperature. The metal *a*, in both the upper and under limb, is such as expands considerably by heat; the metal *b*, such as expands less than *a*. In each limb these bars of metal are firmly connected together by screws. So long as they remain at the temperature at which they were united, no alteration of shape is perceptible in the instrument, but on an increase of temperature, the more expansible metal, *a a*, will stretch, but being bound to *b b*, the effect will be that the two parts, *c c*, will approach each other. D being made a fixed point, it cannot move, and consequently the vertical line, D E, will be elongated. At E, there is a connexion made with the lever of the safety-valve, by means of a small rod passed through a stuffing box. If, then, the safety-valve should stick fast, the action of the thermostat must open it.

I venture to recommend this heat regulator for boilers, having seen it applied very successfully in sugar pans, and also for purposes of ventilation. It has not yet been introduced by engine-makers, but the perfect certainty of its action is beyond doubt. The *gradual* increase of steam pressure may be thereby regulated, and a boiler often saved from damage. We must not, however, consider it a perfect safety-valve: there are explosions which the thermostat would be as ineffectual in preventing as any other safety-valve yet devised.

Mr. Gurney's safety-plug of fusible metal was adopted to prevent accidents from a cause such as he mentions in the following words:—"From experiments which I have made in connection with this subject, I am led to believe that the bursting of boilers is not always occasioned by pressure of steam. I have discovered that at a certain degree of temperature, and under certain circumstances, when water is decomposed, the hydrogen is often formed into a new state of combination with oxygen and nitrogen gas, which compound is exceedingly explosive; so much so, that I believe scarcely any provision that we can make in the shape of a safety-valve would protect the vessel. This was a subject which I was led to some time ago, from some observations which I had made on the combinations of oxygen and hydrogen only. I had some conversation with Gay Lussac on this subject,

Plate 11.

Fig: 8.

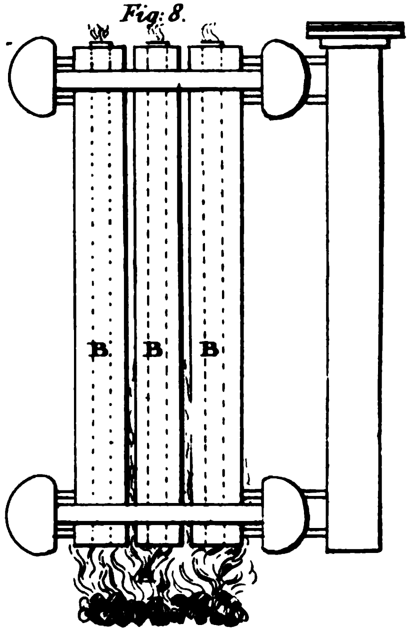


Fig: 9.

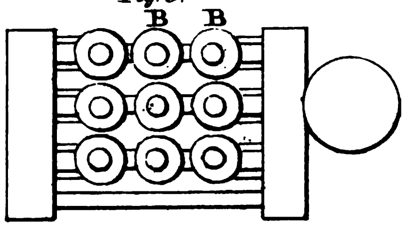
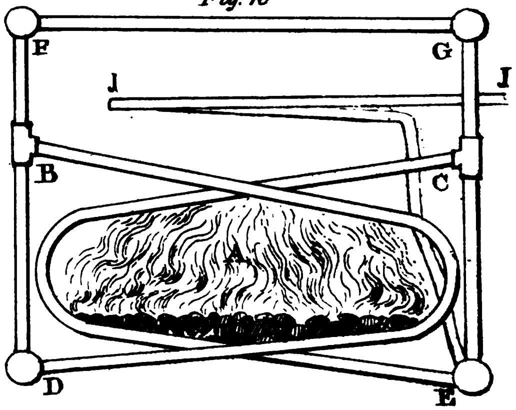


Fig: 10



and he was of the same opinion with myself, particularly that there were different chemical compounds of hydrogen and oxygen gases which at present were not acknowledged. The only one acknowledged in this country is that forming water. A compound of two proportions in volume of oxygen and two of hydrogen, has been chemically combined in Paris, although I believe we never have succeeded publicly in this country. This compound was highly explosive when brought in contact with certain substances.

"I have reason to believe, from some original experiments, that there is a compound of these elements produced under certain circumstances in steam-boilers. The want of water in a boiler is favourable, in which case the temperature is raised and the compound formed; the bursting of boilers, I believe, frequently takes place from this compound coming in contact with substances that will decompose it; and perhaps I might mention this fact, as it is a very interesting one, namely, that boilers often burst when the valves are known to blow at a pressure very considerably lower than the boiler has been proved to.

"I would state a fact, which was mentioned to me by my friend, Sir Anthony Carlisle, which throws considerable light upon the subject, and first led me to my suspicions and experiments respecting it. The case was, that a boiler at Mr. Meux's brewery, with an open top—a common caldron—burst with a violent explosion. I believe one man was killed, and two very severely scalded. There was no cover at all on the vessel. This phenomenon, upon inquiry, appeared to be occasioned by gelatinous matter, forming a crust, a film, or blister, and prevented the contact of water with the bottom of the boiler; the bottom of the boiler, consequently, got hot; the compound I alluded to was formed; the rupture of this film, and the sudden contact of water against the hot surface below, produced such an immense and sudden volume of steam that it burst the boiler. I would explain it by saying it was analogous to the bursting of a gun, in which case an ounce or two of shot is placed only against the charge. Whenever there is a sudden formation of elastic matter, and there be ever so small a weight opposed, the shock will be very great, and a gun will frequently burst though there is not an ounce of shot in it, and which charge may be considered in the light of a safety-valve in this case."

It has been insisted that many sudden explosions have arisen from decomposition of water—from the water being changed into hydrogen by the over-heated metal having abstracted the oxygen. That hydrogen is often found, there can be little doubt, every person accustomed to small boilers, such as are used in steam-carriages, must have perceived a smell of dry hydrogen which often escapes from the valves. When hydrogen is formed, the water is repelled from the bottom, and the permanently elastic gas becomes very intensely heated by its contact with the heating surface. In such case a small stream, or a few drops, of the incumbent water happening to fall into the intensely heated gas, will immediately flash into steam of strong pressure.

Some have supposed that the hydrogen having formed an explosive mixture, with any atmospheric air which may have entered the boiler by the pump, is ignited by the intense heat.

The elastic fluid, whatever it be, is suddenly formed, and not only does it blow out and throw to a distance the iron of which the boiler is formed, but large quantities, nay, all the water, is thrown out by the same elastic force. Had the explosion been nearly at the surface of the water, the water might not be blown out. The evil

Fig: 5.

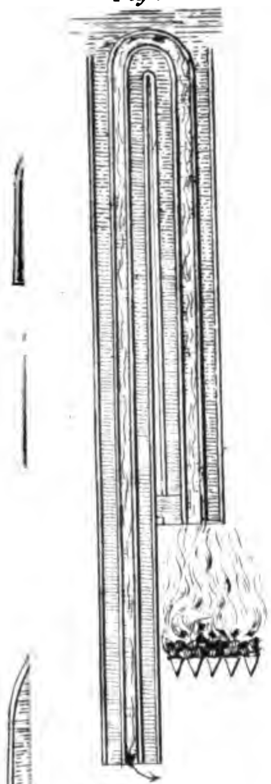


Fig: 6.

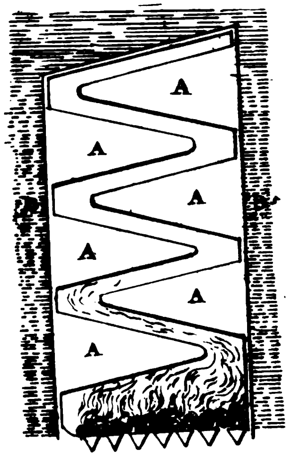


Fig: 7

Fig: 8.

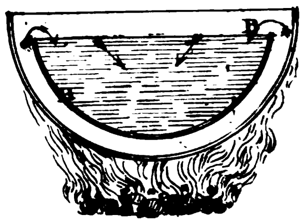


Fig: 9.

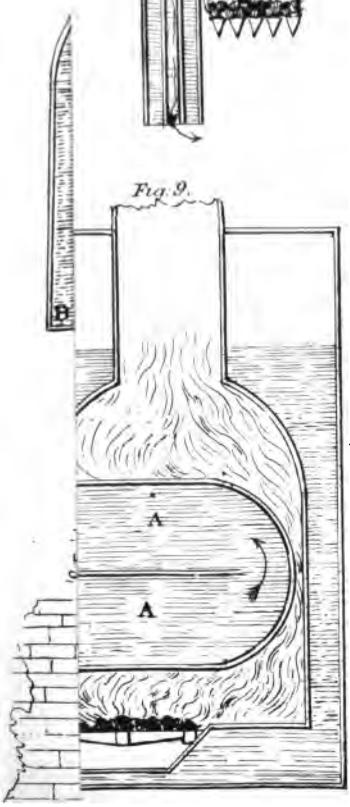
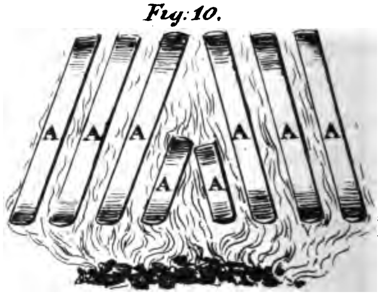


Fig: 10.

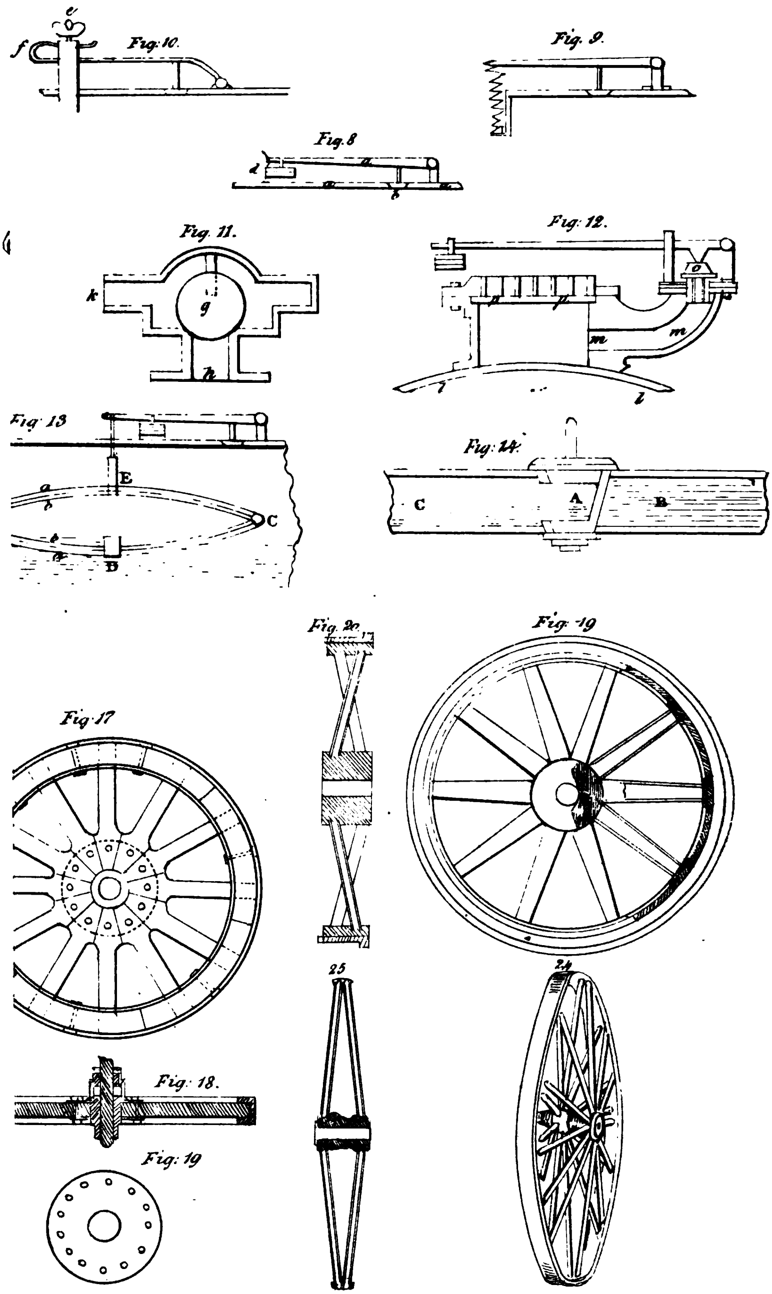


seems to have its origin under the surface, at the centre or altogether below the water, from which it cannot escape through the water. This resistance of water to the passage of elastic vapour through it, is great. The elastic fluid suddenly generated is confined, not merely by the surrounding and incumbent water, but also by the sides of the boiler; it makes an effort to escape, resistance augments its energy, and at last an explosion, proportionate to the difficulty offered to the escape of the elastic fluid, takes place. In this particular, a steam-boiler explosion, resembles an explosion of gunpowder. A quantity of loose gunpowder when ignited is harmless, but the same measure when confined to the close chamber of a gun, and then exploded, exerts a power many hundred times more than atmospheric pressure. There is an instance in which the vapour generated from water has been found vastly stronger than the explosion of gunpowder; this is, "when water is thrown upon melted copper, for here the explosion is so strong as almost to exceed imagination, and the most terrible accidents have been known to happen from such a slight cause as one of the workmen spitting in the furnace when copper was melting." Such an effect does not take place when water is thrown on melted glass, although, in this latter case, the temperature is as great as that of melting copper; nor is it observable when water is thrown on heated iron, although, in this last case, decomposition of the water is effected.

The theory of "latent heat" may offer a reason for some explosions. Dr. Black used to express his theory thus: "When a solid body is converted into a fluid, there enters into it and unites with it a quantity of heat, the pressure of which is not indicated by the thermometer, and this combination is the cause of the fluidity which the body assumes. On the other hand, when a fluid body is converted into a solid, a quantity of heat separates from it, the presence of which was not formerly indicated by the thermometer; and this separation is the cause of the solid form which the fluid assumes."

Thus, ice, when converted into water, absorbs about 140° (Fahrenheit) of heat; and water, when converted into steam, absorbs 1000° of heat, without becoming sensibly hotter than 212°. The latent heat absorbed by water, when passing from a state of water to a state of permanently elastic fluid (hydrogen), is not ascertained. When a cubic inch of water, already heated to 212° in a close box, is placed in such a position as to receive more heat, the law of nature will prevail, and the close box will give way that the one cubic inch may expand into 1700 cubic inches. Now we know that if this one cubic inch of water be decomposed, the hydrogen gas alone will occupy, not merely 1700 cubic inches, but many thousand cubic inches. Such an instantaneous change of bulk must produce an instantaneous expansion.

It may be objected that the fire under a boiler is not so intense as to produce this sudden jump without giving ample warning; and yet it produces the sudden jump from water at 212° to steam, giving no other warning than the cracking or singing noise which every person has observed just before a kettle boils, and we know that *there is almost always a cracking noise* for about a minute before a boiler bursts. There are other changes than ebullition and condensation constantly proceeding in a boiler; there is crystallisation, forming the hard triplicate salt, commonly called "fur," which consists of carbonic acid, silica, and alumina. At their formation into "fur," latent heat must be dissipated, and if by any process the latent heat be restored to the whole of the carbonic acid gas, it will assume its former bulk and expand with a volume certainly sufficient to rend the boiler. An instance of such sudden liberation is to be found in fulminating powder, which is composed of sul-



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phur, saltpetre, and subcarbonate of potash; the last mentioned containing much carbonic acid.

There are, however, in all probability, within the boiler more of the various substances found below the surface of the earth than the carbonic acid, silica, and alumina, already detected; with these, no doubt, an immense quantity of the fixed part of aerial fluids is united, and the electrical changes, always attendant on the phenomena of crystallisation, are sufficient to restore the aerial fluids to an elastic state.

The electric changes which are continually taking place in boilers, have engaged very little, if any, of the practical engineer's attention. That they ought to be the subject of his inquiry, is evident; because electricity is produced by *evaporation*, by *disengagement* of gas, and by *disruption of solid bodies*—all of which producing causes are known to exist in every boiler. We have often heard of flashes of light from the boiler—of the bodies of sufferers having exhibited marks of burning by flame, and scalding by steam or water, in the same instances—and many deaths from explosion are on record, where no external injury could be discovered. From all which, it appears that there is no sure preventive of explosion, and that where steam boilers are to wend their way through crowded streets, they should be made of such small compartments that an explosion can be attended by no danger to those who happen to be in the immediate neighbourhood of the boiler; and it is to be hoped that legislative interference may prevent the introduction of boilers of large diameter in crowded streets, until such time as explosion is prevented. As yet we cannot completely prevent explosion, but WE CAN RENDER THE EFFECTS PERFECTLY HARMLESS, BY CONFINING THE WATER AND STEAM IN COMPARTMENTS OF VERY SMALL DIAMETER.

CHAPTER V.

LAWS OF MOTION CONSIDERED.

A MASS of inert matter remains at rest by reason of certain forces, which are,

RESISTANCE OF FRICTION,
RESISTANCE OF SURFACE,
RESISTANCE OF COLLISION,
RESISTANCE OF GRAVITATION,

all of which require to be overcome or evaded before we can produce motion in the mass at rest. The different degrees of force necessary to move this mass, will vary according to the applications of mechanical science, and under different circumstances.

FRICTION is that resistance which is perceptible when rubbing one surface upon or against another. It is often confounded with that other "surface resistance" which takes its character from the surface of the road. Mr. Babbage, in his "Economy of Manufactures," relates the results of some experiments in moving a block of squared stone; from which it appears that the force necessary to move such a stone along the floor of a quarry roughly chiselled, was nearly $\frac{2}{3}$ of its weight; to move it along a floor of planks required $\frac{3}{5}$ of its weight; to move it when placed on a platform of wood, and dragged over the same floor of planks, required $\frac{5}{9}$; to move it, when the wooden surfaces were well soaped, required $\frac{1}{6}$ of its weight; to move it on rollers required $\frac{1}{40}$ of its weight; and if the rollers were actuated between the wooden platform and wooden floor, $\frac{1}{50}$. of its weight.

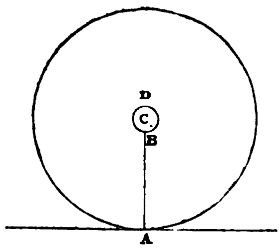
That friction can be much reduced every one knows. A sledge, for instance, requires much more power to move it upon a rough road than a wheel carriage requires upon the same road. In the former there is a large rubbing surface, in the latter the rubbing surface is reduced, and confined to the well-turned axles and boxes, in which the friction is still farther reduced by lubrication. Whilst the carriage travels 16 feet along the road by one revolution of the wheels, the well-polished axle only rubs 12 or 13 inches of a well lubricated bush.

Had this block of squared stone been fitted upon wheels suitable to the edge rails of the Liverpool and Manchester rail-road, $\frac{1}{200}$ part of its weight would have moved it on a level. If, however, the line of motion vary from the level upwards or downwards, gravitation would have its visible influence.

Were this mass of inert matter formed into a spherical ball of marble, with a highly polished circumference, the best arrangement for saving tractive power when moving it, would be to place it upon some other highly polished surface, say a perfect plane.

When the weight to be moved is rested upon four wheels, and caused to move along a rough road, tractive power is increased by the necessity of lifting the mass over the inequalities, when they are hard enough to support the weight without being crushed. If the inequalities are of such a nature as to be crushed down, tractive power is lost in crushing them. If they are loose pebbles, it may be they are pushed aside, and tractive power is wasted in moving them.

Let us investigate this in the manner which M. Gerstner has led us to by his valuable Memoir upon Railways and Canals*. When the wheel is fixed to the axle, the entire weight of the load is rested on the point, A, upon the ground line. The force of traction ought then to overcome all the friction. It is evident that this resistance is more formidable according as the asperities at A are great in number, and the mass transported great in weight.



Let the resistance of friction be represented by m Q, in which Q is the weight sustained, and m the co-efficient depending upon the nature of the rubbing surface. When the wheels are moveable upon the axle, the friction m Q, exerts itself on B, at the contact of the axle and nave. If we represent by a, the radius, C B, of the axle,—and by A, the radius C A, of the wheel; the force, which acting at the circumference of the wheel will be made equal to the resistance of the friction, and may be expressed by $\frac{am\,Q}{A}$; this is as if, the wheel being fixed upon the axle, it had at A a resistance $\frac{ma\,Q}{A}$, this is the resistance that the force of traction, K′, ought to surmount.

When the charge is distributed equally upon two or upon four wheels, each axle carries the half $\frac{Q}{2}$ or the quarter $\frac{Q}{4}$ of the weight; and the resistance to overcome

* Mémoire sur les Grandes Routes, traduit de l'Allemand de M. F. Gerstner, et precedé d'une Introduction par M. P. S. Girard. Paris, 1827.

in this latter case will be $4\frac{m\,Q\,a}{4\,A} = \frac{m\,a\,Q}{A}$, as before. From this we deduce that the draft will be so much the more easy, 1st, That $\frac{a}{A}$ will be small, when large wheels and small axles are employed; on this account iron axles are preferable to wooden axles. 2nd, That the produce $m\,Q$ will be small. Mussembroek, and other old mechanicians, have estimated $m = \frac{1}{3}$. Coulomb, who has made exact experiments, has found that the friction was not proportional to the weight, but the size of the masses and for finely polished surfaces, and he valued, principally for the iron $m = \frac{1}{8}$; making, for example, $\frac{a}{A} = \frac{1}{15}$, $Q =$ 80 quintals*, $m = \frac{1}{8}$; they found, then, for the expression of friction, $\frac{1}{15} \cdot \frac{1}{8} \cdot 80 = \frac{2}{3}$ of a quintal. Upon an ordinary road it is necessary to draw this load, Q, of 80 quintals, to have four horses, of which the power could be reckoned at four or five quintals; hence it is seen that the other causes of resistance are much more considerable than the friction of the axle in the box of the nave.

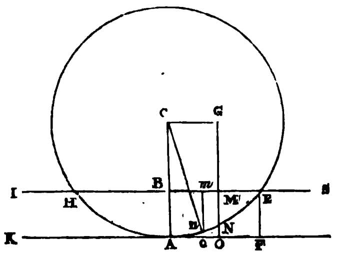
Upon roads of an irregular and ill-constructed cross-section, the carriage taking an inclined position is forced, with its load, against the nave of one of the wheels; and thus a very considerable increment of friction is perceived, because the diameter of the naves is always greater than the diameter of the axles. Suppose, for example, that a rut on one side be elevated a foot higher than a rut upon the other side, so as to expose the carriage to the danger of an upset, we can admit that at that time a fourth part of the weight is pressed upon the nave. It is possible to calculate the friction which results at about a quarter of that which is placed upon the axles. The greatest in-

* A quintal is equal to 1 cwt. 3 qrs. and 25 lbs. nearly.

N

stances of this resistance from friction are observable in ill-made cross roads in the country, and that on well-formed, smooth, and solid roads, it may be avoided almost altogether.

RESISTANCE OF SURFACE is an evil which is brought with the decrease of "friction," because we have now to carry the load upon wheels which bear on two or four tangental points. These penetrate the surface of the roads more or less deeply. Ruts are formed, which vary with the weights transported, and according to the material of which the road is made, and the mobility of the particles. When the wheel rests upon a soft and loose road, I, H, E, it sinks as far as the road material yields, or until the resistance which the cylindrical surface, H, A, E, offers, be counterbalanced by the vertical pressure of the wheel. Let us now suppose the wheel to be drawn in the direction I, H, E. We perceive that the soil behind the wheel does not resume its original condition; it remains compressed, and the wheel leaves a track or rut. It is evident that if the wheel be no longer supported by the hinder portion of the rut, A E, it must be altogether supported by the anterior portion, H A, and which has to be overcome by the force of traction.



The compression being nothing at E, and having its maximum at A, the reaction of the soil is not the same at these two points. It diminishes from E to A. The law which regulates this reaction is unknown; but as the reaction of the ground augments in proportion as the wheel sinks, we may suppose it proportional to an undetermined power, *m*, of the sinking, M N. According to this hypothesis, we shall now estimate the reaction of the soil. Let then,

The size of the rut $= b$;
The greatest depth A B *or* E F of the rut $= h$;
The half chord of the sinking of the wheel, B E = A F $= f$;

$$BM = AO = x,$$
$$Mm = dx,$$
$$NO = u,$$
$$MN = h-u,$$
$$Nn = ds.$$

The weight supported by an unit of the surface at the point A being expressed by W′, we shall have

$$\frac{W'(h-u)^m}{h}$$

for the resistance upon the unit of surface at N; consequently the normal pressure of the soil upon the cylindrical element, N *n*, of the wheel's felloe, will be expressed by

$$\frac{W'(h-u)^m}{h}\ b\,ds,$$

which decomposed according to the vertical N G, becomes

$$\frac{W'(h-u)^m}{h}\ b\,dx.$$

Let us now suppose the diameter of the wheel = A, we shall then have $x^2 = Au + u^2$, or simply $x^2 = Au$*.

By the same process we shall have $f^2 = Ah$, whence

$$u = \frac{hx^2}{f^2}$$

The resistance of the soil from A to N will then be expressed by

$$\int W'\left(1-\frac{x^2}{f^2}\right)^m b\,dx =$$

$$W'b\left(x - \frac{m\,x^3}{3f^2} + \frac{m.\overline{m-1}.x^5}{2.5f^4} - \text{etc.} + \text{etc.}\right)$$

* u being indefinitely small as compared with A, therefore u^2 may be rejected without error.

Denoting, then, by q the reaction of the soil, and taking the preceding integral since $x = 0$ to $x = f$, we shall have

$$q = W' b f \left(1 - \frac{m}{3} + \frac{m.\overline{m-1}}{2.5} - \text{etc.} + \text{etc.}\right)$$

We obtain the pressure upon an element, Nn, of the track, by multiplying this pressure by the arm of the lever CG $= x$. The statistic pressure, taken from A to N being thus expressed by the integral,

$$\int W \left(1 - \frac{x^2}{f^2}\right)^m b\, x\, d\, x =$$
$$\frac{W' b f^2}{2.(m+1)}\left[1 - \left(1 - \frac{x^2}{f^2}\right)^{m+1}\right],$$

we shall have, for the pressure sought between the two limits $x = 0$ and $x = f$,

$$\frac{W' b f^2}{2(m+1)}.$$

This ought to equal the force of traction. If, then, we make that force $=$ K$''$, its momentum will be $\frac{K''A}{2}$, and we shall have

$$K''A = \frac{W' b f^2}{(m+1)};$$

and, consequently,

$$K'' = \frac{f W' b f}{A(m+1)} = \frac{f q}{A(m+1)\left(1 - \frac{m}{3} + \frac{m.\overline{m-1}}{2.5} - \text{etc.}\right)}$$

If we make $m = 0$, which is the case in supposing the resistance of the soil constant at all depths, we obtain

$$K'' = \frac{f q}{A};$$

for $m = 1$ we find $K'' = \frac{3 f q}{4 A}$;

for $m = 2$, $K'' = \frac{5 f q}{8 A}$.

We see that the difference of the value of K is not very considerable.

It remains now to determine the length of the line $B E = f = \left(\frac{h}{A}\right)^{\frac{1}{2}}$, or, which is the same thing, to find the amount of $B A = h$; to effect this, let W be the resistance which the ground offers, when $h = 1$, we shall have, according to the principle adopted, $W' : W :: h^m : 1$; and consequently

$$W' = W h^m = W \left(\frac{f^2}{A}\right)^m.$$

Substituting the value of W' in the value of q abovementioned, we have

$$q = \frac{W b f^{\overline{2m+1}}}{A^m}\left(1 - \frac{m}{3} + \frac{m.\overline{m-1}}{2.5} - \text{etc.}\right),$$

from which we draw

$$f = \left(\frac{A^m q}{W b \left(1 - \frac{m}{3} + \frac{m.\overline{m-1}}{2.5} - \text{etc.}\right)}\right)^{\frac{1}{2m+1}} \text{ and}$$

$$\frac{f}{A} = \left(\frac{q}{A^{\overline{m+1}} b W \left(1 - \frac{m}{3} + \frac{m.\overline{m-1}}{2.5} \text{ etc.}\right)}\right)^{\frac{1}{2m+1}}.$$

We have in making successively,

$$m = 0, K'' = \frac{f q}{A} = \frac{q q}{A b W};$$

$$m = 1, K'' = \frac{3 f q}{4 A} = \tfrac{3}{4} q \sqrt[3]{\frac{3 q}{2 A^2 b W}};$$

$$m = 2, K'' = \frac{5 f q}{8 A} = \tfrac{5}{8} q \sqrt[5]{\frac{15 q}{8 A^3 b W}}.$$

From these formulæ the result is,

1st. That the resistance, K'', proceeding from the ruts increases in proportion to the load, q; it is, then, more advantageous to divide the load upon several carriages than to overload a single one.

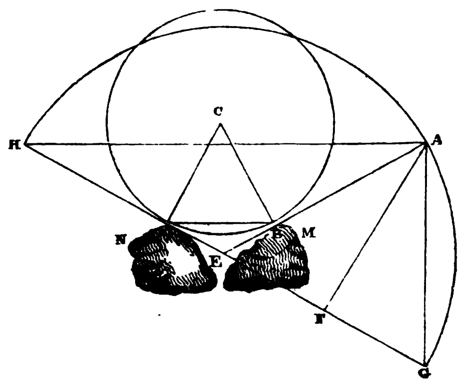
2nd. That upon a soft road the resistance is more considerable than upon a hard one, because f increases as W diminishes.

3rd. That the resistance diminishes as the diameter A of the wheel increases. Thus, in order to overcome the resistance of the ruts, large wheels are preferable to small ones.

4th. Lastly. That the resistance diminishes by increasing the breadth of the felloes; thus broad felloes are preferable to narrow ones for soft roads.

THE RESISTANCE OF COLLISION is owing to stones which form the pavement, or may be on the surface of a road, or to holes in a road.

When a wheel rolls over such, it experiences a shock in passing from one stone to the other, or from one side of a hole to the other. Let B, E, D, be one of these cavities.



Let us conceive E the point of intersection of the tangents to the circumference of the wheel, B E, D E, and let us suppose the velocity is represented by A E = H E in intensity and direction. From the point E, as a centre, and with the radius A E, describe G A H; let fall the perpendicular A F. The force H E resolves itself into two others, the one, A F, destroyed by the shock, and the other, F E, which exists in the direction E D. (We shall return to this again.) It follows that the loss of force is evidently equal to $AE - EF = EG - FE = GF$, and this loss must be compensated by an augmentation of tractive power, if it is wished to have the same force upon the line M N. To avoid a complicated calculation, we shall admit that this force of traction, K''', is a constant, accelerating force. Considering, then, the weight of the carriage to be Q, 2 *gt* being the intensity that the weight impresses to the load Q, at the end of the time *t*, we shall have $K''' = \frac{Q.FG}{2\,gt}$; but we have $FG : AG :: AG : 2\,AE$, whence $FG = \frac{\overline{AG}^2}{2\,AE}$. Now the similar triangles A E G, D C B, giving $AG : AE :: DB : BC$; then $AG = \frac{AE.DB}{BC}$. Moreover, $t = \frac{MN}{v}$, *v* being the velocity with which the space M N is travelled during the time *t*; it happens now $K''' = \frac{AE\,Q\,v}{4\,g\,MN}\left(\frac{DB}{BC}\right)^2$.

It results, then, that this part of the force of traction is proportional to the load; it is known, indeed, that heavy carriages require greater traction than light carriages.

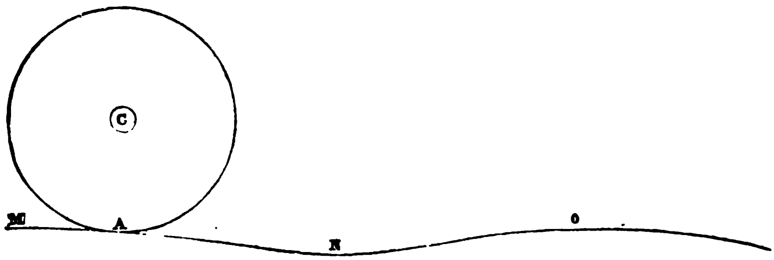
It results, also, that the traction is proportional to the velocity with which the carriage is urged. Thus upon a rough pavement it is more advantageous to go slowly with a heavy load, than to go more quickly with a less weight.

It results, also, that the draft increases in the inverse ratio M N; the less distance there is between the paving stones, the less traction will be required.

Finally, the traction augments in the ratio of the width of cavity to the semi-diameter of the wheel.

Thus large and deep holes are more to be avoided than numerous little holes; and, for the same reason, large wheels will require less tractive power on a rough road than little wheels.

All these propositions are applicable not only to paved roads, but also to those upon which stones are scattered, whilst the prominences and the cavities, which do not occasion jolts, and which form a slightly undulating line, do not present for the horses in draught either advantage or inconvenience. When the descent, A N, is gradual,



and the wheels are in motion, then the draught is facilitated as much as it is retarded in surmounting N O, where the undulations are not too great. The same thing obtains in flat or rounded pavements. The succession of accelerated and retarded velocities do not perceptibly alter the uniformity of movement.

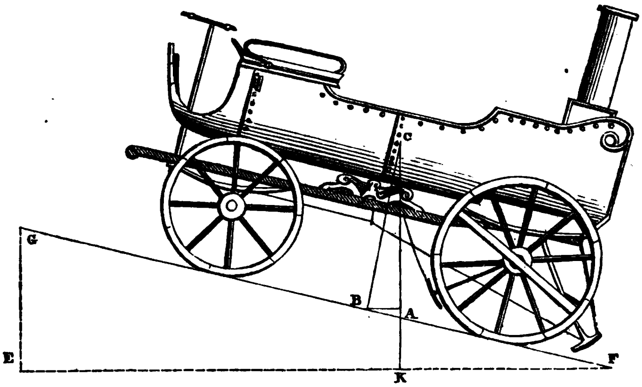
THE RESISTANCE OF GRAVITATION falls now under consideration. The laws of gravitation will certainly help us as much in a descent, as they oppose us in an ascent, yet the converse of the proposition will be so evident, that we need here only go into the question of the opposing force.

We shall borrow our illustration from Mr. Macneill's notes to Sir Henry Parnell's Treatise on Roads.

"When the road is not horizontal, the force of gravity is a great impediment to the draught of carriages, and limits considerably the effect which would otherwise be produced by a horse in drawing a load.

"If it were not for the hills that are usually met with on turnpike roads, one horse would do as much work as four; for it is well known that the force of draught must be increased in proportion to the steepness of hills: the quantity of that increase is thus determined:—

"Suppose a wagon resting on an inclined plane, F G;



and let C be the centre of gravity of the wagon and load. Draw the line C B perpendicular to the surface of the hill, and C A perpendicular to the horizon; let this last line represent the force of gravity, or weight of the carriage and load. This force is equivalent to two others, represented by the lines A B and C B, in magnitude and direction. The force represented by C B is the pressure of the carriage on the surface of the road, and that represented by A B is the force independent of friction, which acts against the carriage going up hill, or tends to force it down hill.

"Now this force may be found as follows: the triangle A B C is similar to the triangle A K F; for the angle F A K = the angle C A B = the angle E G F; and the angle A B C and A K F are each right angles; therefore, A C : A B :: F A : A K; but F A : A K as the length of the plane is to its height, that is, A C : A B :: $l : h$; and as the line A C represents the weight of the carriage, or W, we have W : A B : $l : h$; or A B $= \frac{Wh}{l} =$ the force represented by the line A B. The power required to draw a carriage on a horizontal may be represented by the formula $P = W\left(\frac{rm}{R} + \frac{3f}{4R}\right)$ for a broken stone road, and $P = W\left(\left(\frac{rm}{R}\right) + \frac{v^2}{4gMN}\left(\frac{DB}{BC}\right)^2\right)$ for a paved one.

We then have, for the power required to draw a wagon or coach up an inclined plane, the formula $P = W\left(\frac{h}{l} \perp \frac{rm}{R} + \frac{3}{4}\frac{f}{R}\right)$, if the surface be of broken stone; or $P = W\left(\frac{h}{l} + \frac{rm}{R} + \frac{v^2}{4gMN}\left(\frac{DB}{CD}\right)^2\right)$, if the surface be a pebble pavement; and for the power required to draw the same wagon down hill, the same formula, only making the sign of $\frac{h}{l}$ negative.

"In these formulæ W = the weight of the wagon, wheels and load; for although it might at first sight appear that we should make use of the weight on the axle, or that represented by the line C B, to calculate the resistance, yet it is not so; for the pressure on the axles will be equal to the joint action of the weight on the axles and the moving power, and this will be the force represented by the line A C or W, so that no correction of the weight is necessary.

"The resistances arising from part of the weight being thrown from the front axles to the hind ones, in consequence of the inclination of the traces, and the line of draught not passing through the centre of gravity of the carriage, may be omitted in general investigation, also the correction that should be applied to the resistances where the carriage is on an inclined plane, because it is evident that there is less weight on the surface than if the carriage stood on level ground, and also from the hind wheels bearing a greater pressure than the front ones, in consequence of the line of gravity falling nearer to the hind wheels, as the difference which will take place in the draught in consequence of these will be inconsiderable in general practice, and, should extreme accuracy be required in any particular case, it will be easy to make the necessary calculations.

The following experiments were made with the wagon the axles and wheels of which had been previously made use of for experiments on friction.

"1. Half a ton of stone was put in the wagon, as nearly as possible in the centre between each axle-tree; the waggon was then drawn over a timber platform, perfectly horizontal, by weights suspended from a line: to effect this it required 50¾ lbs.

"2. A ton of stone was placed in the wagon, half a ton over each axle-tree; and the power required to draw the wagon over the same surface was 70 lbs.

"3. A ton and a half of stone was placed in the waggon, and distributed equally over each axle-tree; the weight or power required to draw the wagon was then found to be 90 lbs.

"The resistances arising from the friction of the axle-trees in the above experiments were then calculated for each wheel, and the total resistance arising from the axles thus determined was subtracted from the draught or power found by experiment as requisite to draw the wagon; the difference gave the resistance of the surface caused by the penetration of the wheels into the timber surface.

"The results of these experiments are given in the following Table:—

Weight of wagon and load in pounds.	Power required to draw the wagon.	Resistance of the axles.	Resistance of the surface.
2240	31.0	13.0 } 23.6 10.6 }	7.4
2800	52.0	16.2 } 29.5 13.3 }	22.5
3360	70.0	19.5 } 35.4 15.9 }	34.6
3920	91.0	2.7 } 41.3 8.6 }	49.7

"By a considerable number of experiments with the same wagon, on roads of different kinds, the draught was found to agree very nearly with the results calculated from the empirical formula, $P = \frac{W + w}{93} + \frac{w}{40} + v$; in which W = the weight of the wagon; *w*, the load; *c*, a constant number, which will depend on the surface over which the wagon is drawn; and *v*, the velocity, in feet per second. By putting $v = 3.7$, which was the velocity used in the foregoing experiments, the constant number for a timber surface was determined, and found to be equal to 2.

"For other surfaces the value of *c* may be taken as follows:—

On a paved road	2
On a well-made broken stone road, in a dry and clean state .	5

On a well-made broken stone road, covered with dust . . .	8
On a well-made broken stone road, wet and muddy . . .	10
On a gravel or flint road, in a dry, clean state	13
On a gravel or flint road, in a wet, muddy state	32

On an inclined plane, the above formula becomes $P = \frac{W+w}{93} + \frac{w}{40} + v + \frac{h}{l} . \frac{W+w}{1}$, for a common stage wagon; and $P = \frac{W+w}{100} \times \frac{w}{40} \times c\,\frac{h}{l} . \frac{W+w}{1}$ for a stage coach.

CHAPTER VI.

ROADS.

THE province of the engineer is to surmount the difficulties which are presented by "FRICTION," "GRAVITATION," "COLLISION," and "ROAD SURFACE." He must consider well the *traffic* upon his intended line of road, and determine whether a saving of tractive power will compensate for the outlay of capital required to form a road. The quality of the road must depend on the means of making and supporting it; and there even are situations in which it would not be judicious to make any road at all.

The FRICTION of axles and boxes, of journals and brasses, and pervading the working parts of any carriage or locomotive engine, is inherent in the machines to be moved, and little, if in any degree, affected by the ordinary differences of surface upon which such machines are made to travel. This we have established by the preceding chapter.

GRAVITATION has also been examined in the last chapter. It is too little regarded in the practice of railway engineering. Where the reduction of "surface resistance" seems to have lulled that inquiry which it becomes all the members of a scientific profession to institute into every one of the retarding forces. The resistance offered by the law of gravitation, to the ascent of a body, is the same whether the body be rolled up a hill or up the same inclination of a railroad.

Surface resistance will be lessened certainly by the railway, but gravitation will be the same. We have already seen, by the last chapter, that these resistances are distinct and separate, and must not be confounded.

To move a body up hill, is to lift it up the height of the line which joins the extreme end of the hill with the base, and at right angles to the base. Hence a body to be moved up a rise of one foot in twelve feet has, in fact, to be lifted one foot. The movement could either be effected by rolling it up the inclined plane (the hypothenuse of the right-angle triangle), or by rolling it along the plane, and then lifting it up the one perpendicular foot of rise; these two last lines being the base and perpendicular of this right-angle triangle.

The long train of waggons on a rail-way can easily be rolled along the *plane*. There the saving, when compared with a turnpike-road of average quality, is admitted to be great; but when the train on the rail-way comes to ascend, the *advantage* of a rail-way is lost. Mr. Wood states, that if a locomotive-engine draw, by the adhesion of its four wheels, 67·25 tons on a level, it will only draw, by the same adhesion, 15·21 tons up an inclination of one in one hundred; and he gives data for calculating that a rail-road locomotive-engine, working by the adhesion of the wheels on the rail, will not ascend an inclination greater than one foot in twenty feet, or, perhaps, one in fifteen. Its power of doing any useful work, on such an inclination, has vanished.

Mr. Wood has calculated a valuable table, illustrative of this, and which I have copied in Appendix E, together with the Rev. James Adamson's formula.

It must be observed that there is a difficulty in rail-road locomotion, when ascending any inclined plane, which difficulty is not to be met with in locomotion on roads of inferior surface. The driving wheels of a railway engine slip round upon inclined rails, whilst they hold well on a turnpike or stone road. This decrease of surface resistance, purchased at the immense cost of a railway, is the source of the difficulty on a very moderate inclination.

Now we have seen, both from Mr. Stone's evidence and letter, and from Sir Charles Dance's confirmation of them, above quoted, that one of Mr. Gurney's engines drew eleven tons (including the weight of the carriage) up an ascent of one in twenty.

COLLISION has been examined also in the last chapter. Some railway engineers contend that they avoid all collision by their railways. Upon the Liverpool and Manchester line, it is acknowledged by Mr. Stephenson to be great. "The violence," says he, "to which the wheels" (and consequently the rails on which they travel) "are subjected, in such quick travelling, is so great, that no wheels tried on that railway have been found sufficiently safe and durable" until he introduced his patent iron wheels, plate XIII, figs. 20 and 21.

The road is composed of separate rails of iron, laid one following another: there are frequent breaks in the line to allow for expansion by heat and contraction by cold. The rails rest upon stone sleepers, placed three feet apart, and as heavy weights pass along with great velocity, these sleepers are driven deeper into the ground; some more so and some less. The jolts at passing over these places are quite easily perceived, and the carriages are deflected from their true course and forced against the rails, alternately to one or other side.

ROAD SURFACE resistance has of late years been lessened by numerous methods: by railways, tram-roads, pavements, and by good turnpike roads.

Mr. McAdam has introduced a system which has obtained great celebrity, and of which the peculiar features may be given in words put forth by Mr. Macadam himself:—

"That a foundation or bottoming of large stones is unnecessary and injurious on any kind of subsoil.

"That the maximum strength or depth of metal requisite for any road is only 10 inches.

"That the duration only, and not the condition, of a road depends upon the quality and nature of the material used.

"That free stone will make as good a road as any other kind of stone.

"That it is no matter whether the substratum be soft or hard."

That such a system should ever have been adopted is only to be accounted for by the ignorance which for so long clouded the subject. The expense of it will appear from the evidence given by Mr. Johnston, an eminent pavior of London, to a committee of the House of Lords (May, 1833). "He proved that a Macadamised or broken stone road requires for keeping in repair the first year, and every year after, two coats of three inches thick to allow for wear:" and he estimates

	£.	s.	d.
The first cost, per superficial yard . .	0	7	6
Two coatings, at 1*s*. 9*d*. each per yard, for 10 years	1	15	0
Cleansing, at 10*d*. per yard, for 10 years .	0	8	4
Per yard .	2	10	10

No firm foundation being made, a Macadam road,—although it may in some cases look firm and compact,—is soon formed into hollows, here and there, and the surface becomes of an undulating form. Constant attrition of the sharp stones against each other, when changing their relative positions, as they do incessantly, causes dust in summer, and mud in winter. The stones may appear to be bound together, but they are not; and the above quoted fallacious principles upon which they are laid, cause them to wear away each other, to an extent far beyond that which would be caused by horses' feet or carriage wheels.

Numerous instances by which the Macadam system is found in practice to be defective, could be given*. Blackfriars Bridge requires for keeping it in a proper state of repair, 1,000*l.* per annum, when macadamised; but it was kept in repair, as a paved road way, for an annual average sum of 120*l.*† By a return presented to the House of Commons (1827), it appears that the first cost of converting 1 mile 250 yards from a London pavement into a broken stone road, was 12,842*l.*; the annual expense of maintaining which road has been 4,003*l.*, or 1*s.* 9*d.* per superficial yard square.

Mr. Telford, who has made more miles of new road than any engineer in this kingdom, has, in the principal roads constructed by him, under the authority of Government, laid down a good firm pitching of large stones by hand, with the broadest side downwards, and filled in the chinks with chips closely driven home. This pitching is about eight inches deep at the middle of the road, and diminishes in thickness towards the sides, where the depth of it is, perhaps, three or four inches. Over this is laid broken stone, each piece of which will pass through a circular guage, or ring, 2½ inches diameter, and a binding gravel is added above. The surface of a 30-foot road is the segment of an ellipse, the versed sine of which is about 9 inches.

Mr. Macneill, assistant of Mr. Telford, and resident engineer upon the Holyhead line of road, has bestowed on the subject much attention; and some interesting information, given by him, is to be seen in the Transac-

* See Sir Henry Parnell on Roads.

† Ibid.

Civil Engineers. From all of
good foundation is the first

were formed with large stones
flint and pebble; then cement,
of wooden block, granite, or

s used for foundations; and in
, they have four or five feet of

planted in marshy ground, and
t foundation; above this green
inches thick; then, above all,

is used for marshy ground, in
the willows are used in France;
ys undulate like a blanket.
ndation may be had by digging
ing and burning it.
ely become general for founda-
cannot be had: it forms a very
dense and hard combination, preventing the passage of damp and water. It is composed of sand, lime, and gravel. The lime being used hot, combines with the sand, and forms a mortar to fill up the interstices of the gravel. The whole becomes a hard concrete mass, and there is no rubbing of one point upon another, as in a loose gravelly road. The gravel, however, not being perfectly spherical in its particles, as cannon balls are, will in its bulk bear a proportion to the cube of 3 to 1, whilst cannon balls and their interstices would be as 2 to 1. Three parts of well screened gravel and one of mortar, would therefore be the proportion.

The hardness depends on the quality of the mortar, which is formed by the lime and the small portions of sand adhering to the particles of gravel; one lime will bear a larger proportion of sand than another, and their quality being best known in the particular district where required, the workmen may be depended on; but as the interstices of large gravel may be filled by gravel of smaller diameters, well sifted, and again these remaining interstices filled with still smaller gravel, the quantity of mortar requisite may be reduced to one-tenth or one-twelfth without any prevention of firm adhesion: as little water as possible should be used.

Mr. Macneill, with a view to remedy the evils presented by clay soil near London, introduced a cemented gravel. It was formed of 7 parts gravel, 2 parts sand, and 1 part cement. The sand and cement were well mixed (dry) in a large shallow trough—gravel was added—as little water as possible used, and the whole mixture then cast on the the ground, and properly trimmed. Before it was allowed to set, furrows were made in it, which, when the mixture has hardened, hold the broken stones, of which the surface is made, and help to fix such surface to this cement foundation. The tractive power on a level road, of this description, averages 40 lbs. for a ton, or $\frac{1}{56}$ part.

In the Highgate Archway-road, near London, a foundation of this kind, six inches deep, was laid by Mr. Macneill; the proportions being $\frac{1}{10}$ Roman cement, $\frac{1}{10}$ sand, and $\frac{8}{10}$ stones. This was covered with three inches of broken stones, and has for some years stood the hard frosts, and other causes of destruction, extremely well. The cost of this cemented foundation was from 12*s.* to 15*s.* per yard long, of a width of six yards, or little more than 2*s.* per square yard.

Mr. Macneill's extensive practice in road engineering, under the Parliamentary Commissioners, led him to think of a good measurer of tractive power, and he contrived the following beautiful machine, by the use of which the comparative merit of roads, and the state of repair in which they are kept, may be accurately ascertained and registered by persons interested therein, without their having recourse to any mathematical investigation. This dynamometer or pyrameter originated in an attempt of the inventor to adapt Marriot's scale, or spring weighing machine, so as to ascertain from it the amount of the horse's draught; but the stepping motion of the horse created a quick succession of vibrations, which prevented any one from reading off the figures indicated. This confusion of vibrations must always prevent the simple adoption of any species of spring weighing machine. To remedy the evil of these vibrations, the inventor applied a piston, working in a cylinder full of oil, and connected with the spring in such manner that, when any power or force is applied to it, the piston is moved through the fluid. The connexion of the spring and index with the cylinder is by means of a lever working on a pivot: the arms of the lever are of unequal length; the tail piece of the spring and index is connected with the short arm; at the extremity of the long arm the piston rod is connected; the piston rod, after passing through a stuffing box in the cap of the cylinder, is screwed into a circular plate of thin brass, perforated with small holes; a square notch is cut out of one side of this circular plate of brass, the use of which will shortly appear.

The resistance which the oil offers to the passage of the perforated brass piston plate, prevents the sudden jerks from being marked on the index, and which we have just seen are so much to be avoided; whilst, at the same time, the piston will move through a space proportioned to the intensity of the force exerted by the horse, and the same will be indicated accordingly upon the dial of the instrument. If the pulls rapidly succeed each other, the piston will move slowly out, and the hand upon the index will turn round steadily and uniformly until the power be balanced by the spring.

The dial plate is graduated in pounds, and the spaces of measurement on its circumference decrease in size from Zero upwards, so as to compensate the increased force which is required to affect the spring at its increased state of tension: by this arrangement the index hand does not pass over equal spaces, when equal forces are applied in different states of tension of the spring. This it will be seen produces an evil which must be obviated: the piston will not pass through equal spaces in the cylinder, and the vibrations must consequently be greater in the higher numbers, because the velocity of the piston being less, the resistance to the piston, in passing the fluid, will be less, at the same time the power opposed to it is greater. The evil is obviated by the square notch, which we have seen has been cut from the circumference of the perforated brass piston plate. A narrow strip of brass, of a wedge shape, is soldered into and from end to end of the cylinder, and the notch of the piston plate travels upon it. When the piston plate is at the end of the cylinder where the sharp end of the wedge is, the notch in the plate will be almost completely open, and the fluid may flow through the large aperture with ease. But as this piston plate is, by the action of strong tractive power, brought up to the top of the cylinder, the thick part of the wedge will have filled the notch completely, the resistance to the passage of the piston plate being less as the notch is left open, and greater as the notch is closed, and the change is gradual, and made to compensate the gradual change of power in the spring; a compensation similar to that afforded by the fusee of a watch.

The dial plate is fitted not only with an index and hand for determining the tractive power, but also with a magnet and card for ascertaining the bearing; a pendulum which points its vibrations on a small dial, and shows the inclinations; a time-piece; and also an index and hand which show the distance travelled.

The reader who has perused chapter V. will see how the inclination being found, a correction may be calculated, and the mere surface resistance ascertained, and it must at once occur to him that by such an instrument the comparative value of an edge railway surface, a stone tramway, a pavement, or a hard turnpike road, may be determined.

Suppose it be required to determine the best surface on such different roads, or on roads repaired with different descriptions of road materials. Let the instrument be run over each portion of the road, and the average power noted, also the rates of inclination as shown by the instrument, or a spirit level, then reduce the average draught over each rate of acclivity to what it would be if it were horizontal; the comparison of the corrected draughts will show the friction and resistance arising from the surface in each case. Thus, suppose the average draught over a portion of the road, which has been repaired in an excellent manner with granite well bound, and which rises 1 in 20 to be 78 lbs. The correction for 1 in 20 is $39\frac{2}{10}$ lbs. The resistance of the surface and friction of the axles is therefore $78—39\frac{2}{10}$ or $38\frac{8}{10}$.

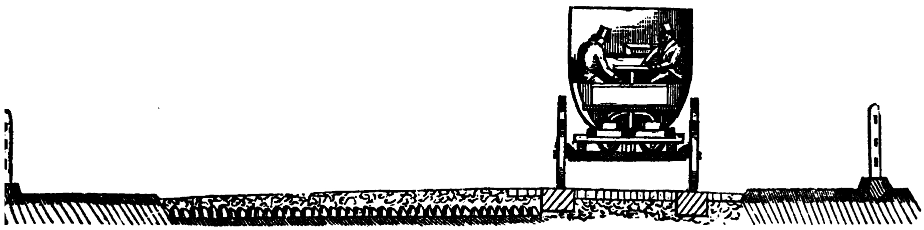
In the same way, suppose the draught over another portion of the road which rises 1 in 10, but which has been made with blocks of granite*, is found to be $90\frac{10}{10}$ lbs. The correction for 1 in 10 is $78\frac{4}{10}$ lbs., therefore the friction of the surface, or what it would be if it were horizontal would be $90\frac{9}{10}—78\frac{4}{10}$ or $12\frac{5}{10}$ lbs. only; the difference between this granite surface and the common road surface will therefore be $38\frac{8}{10}—12^{5}$ or $26\frac{3}{10}$.

* As noticed hereafter, and as intended on the Holyhead line of road. See Appendix G.

The best surface hitherto used for such roads, is made of Northumberland whin-stone, and of a stone from Dudley, called Nuneaton-stone; but I am disposed to think a cemented gravel road will be found desirable: it can be easily patched. Stone ways have been introduced in many situations, for the wheels of carriages to run upon. In Cornwall, they have been extensively used, consisting of hard stone; but not of granite. For long they have been used at and near Milan; and the ruins of Pompeii prove their use to have been known to the Romans.

In 1829, Mr. Walker paved the wheel-ways at one side of the Commercial Road, between the West India Docks and Whitechapel, London (a distance of two miles), with granite blocks, all of one form and size, and so dressed as to fit closely to each other: the whole being laid upon a firm bottom of cement and gravel. Upon this road, Mr. Walker found, that one powerful horse was able to draw 30¼ tons. upon a level, at the speed of four miles per hour; but the exertion of the horse was "too great to be continued for any considerable time;" and hence this must not form a basis for calculation. Mr. Walker has, however, shown, that upon the level, ten tons gross may be considered a proper load for a draught-horse. But to express the power of traction more conveniently, it may be stated as one ton, moved by $12\frac{5}{10}$lb., or $\frac{1}{180}$; a tractive power, which is very little more than that (of 10lb., or $\frac{1}{224}$) upon a railway. The roughness of the stones (when new) is compensated for, by the wheels which may be used, not having the flaunches required on a railway. The facility of turning off and on such a road, and of crossing it, the advantage being unconfined to any one species of carriage, or branch of trade,—being open to all,—being $\frac{9}{10}$ths cheaper in construction than any railway,—and costing for annual maintenance less than $1\frac{1}{4}$ per cent of the acknowledged sum required to maintain the Liverpool and Manchester railway* compensate amply for the mere difference of tractive power.

Mr. Macneill proposes to construct such a road as this from London to Birmingham, for the "London, Liverpool, and Holyhead, Steam-coach and Road Company." Steam carriages, and all other descriptions of coaches, will be allowed to travel upon it. This wood-cut represents the cross section of the road, with the granite trams, or blocks, at one side, and a stone pavement between the rows of granite; with a steam carriage upon the trams.



The use of iron, for the wheels to run upon, although not new, may be so considered for purposes of general traffic. A ton weight may be moved, as we have already said, upon such a surface, with a tractive power of only 10 lb, or $\frac{1}{224}$th part; "and where applied in proper places, and under judicious arrangements, cannot fail of becoming highly beneficial." But nothing can be more delusive than to suppose that because railroads are better (in this respect) than "high-roads, they will answer *every* where; and yet the existing rage for them would seem to justify such an opinion †."

* By Reports of the Directors, "maintenance of way" for blocks, sleepers, chairs, ballast and wages, amounts to more than 400 *l.* per mile! The granite tramroad, just mentioned, cost for annual maintenance and repair 5*l.* per mile annually, for five years, and this notwithstanding a greater amount of traffic than on the railway.

† Report on Railways, made by Charles Silvester, Civil Engineer.

The Liverpool and Manchester railway is formed of an entire double-way of parallel edge-rails, 4 feet 8 inches apart. One line of these (consisting of two rails) is used for the transit towards Manchester; the other line is used for the transit to Liverpool. There are also provided, here and there, "sidings," upon which a locomotive and its train may be drawn, in order to allow free passage, in case of another train overtaking the first, or by these "sidings" the latter may pass round the side of any train stopped upon the line. Communication with the towns, on one or the other side of the line, is provided for by oblique curvilinear openings.

The rails are formed of wrought iron, after the patent of Mr. Birkenshaw (sealed 1820).

On plate VII. an elevation of the rail is seen under the locomotive engine. Fig. 3, is a plan of the same rail. Fig. 4 is a section of the same, through the middle. Fig. 5 shows the mode of joining the wrought-iron rails, to the chairs, or pedestals.

These rails are about two inches broad, where the wheels travel, and one inch thick; and are in lengths of 20 or 25 feet each. Long rails are recommended by the patentee, in order to reduce the inconvenience of numerous joints; and by this arrangement, he says, "the shocks, or jolts, to which the carriages are subject, from passing over the joints (very much to the injury of the machinery), are also diminished." See 182 and 192, where collision is treated of.

On the Leeds and Selby railway, Mr. Walker is introducing a piece of felt between the saddles or chairs and the stone blocks on which they rest, with the view of preventing the wear of the stone-sleepers, which is so much observed on the Liverpool and Manchester railway.

At New Orleans, and other parts of North America, railways are now forming without chairs. The rails are stronger than those in use at Liverpool, although they are $2\frac{1}{2}$ lbs. lighter, per yard. These rails are fixed, by laying down the blocks of stone at the proper distances, without being particular as to the uniformity of their height by 2 or 3 inches, On these stone-blocks, pieces of wood are fastened, which are adzed off to a level line, and then the rails are laid down and fixed. Thus the stone-sleepers may be bedded quite solid, and the rails be easily adjusted by new pieces of wood.

The Liverpool and Manchester company keep an extensive police establishment, in order to guard the road—to prevent or give notice of any obstruction, and to render assistance in cases of accident. A continual line of police communication is kept up at an expense of 2,250*l.* per annum*. " Their directions to the engineer are given by signal. When a train approaches within a certain distance of a station, the policeman presents himself, and signifies a clear road, by assuming an erect posture, with his arm outstretched: should he take the position of ' stand at ease,' the engineer is aware that some obstruction exists. When a passenger is waiting at the station a red flag is hoisted by day, and a swinging light exhibited at night. In travelling in the dark, the last carriage of every train carries a revolving lamp, one side of which is red, and the other blue. As long as the train is in motion, the red light presents itself to whatever follows; but at the instant of stopping, the blue light is turned outward: the engineer of the next train instantly sees this change, and is enabled, by checking the velocity of his engine, to avoid a collision that would be tremendous," and which has been already attended by the most distressing consequences. " The fire of the engine is sufficient to give warning to the policeman, or to any object upon the road, of the approach of a train.

* See Reports of Company, 1832.

"Each engine is immediately followed by a tender, or light open vehicle, containing a supply of fuel and water, with the engineer and his attendant; and to this is attached a train of from five to twenty carriages, according to the number of passengers and goods.

"The passage carriages are divided into three classes; and are made to resemble four coach bodies joined together upon one frame. Those of the first class contain seats for eighteen passengers, three abreast; each seat being separated by arms, and numbered. Those of the second class carry twenty-four passengers, four abreast, and have the seats likewise separated and numbered. The third class are open carriages, containing seats for twenty-four passengers. Each train of carriages is attended by one or more guards, who have seats on the outside. To enable private carriages to travel along the railway, flat frames are provided, upon which the carriage is raised, and its wheels firmly secured upon the platform, by moveable grooves.

"The luggage-wagons, for the conveyance of goods, are square open carts; each of which is furnished with a tarpauling, to protect the bales of merchandise from the weather. The wagons for conveying coals are likewise open carts, made wider at the top than the bottom."

The wheels of the locomotive engines, and all the wheels of the train are made with the flaunches on the inside, as shown by plate VII.

By a smooth well-made London pavement, it appears from the 7th Report of the Holyhead Road Parliamentary Commission, that the tractive power necessary to move a given weight on a level, is only $\frac{1}{100}$. In every pavement, however, the stones should be accurately fitted to each other, and bedded on a good foundation of broken stones, put on in layers of four inches at a time until they be twelve inches thick, and then the *well-dressed* pavement of rectangular stones placed upon it. "If," says Mr. Macneill in his evidence, "you take twenty miles of road near London, and also take the repairs of the roads for twenty years into account, I should say paving would be the cheapest kind of road. The great defect of all the London pavements arises from want of a strong and firm foundation. In Fleet Street, and some others, this has been partly accomplished of late, but certainly not as perfect as it might be. If on the road from this to Birmingham there were a portion laid off on the side of the road for steam-carriages, which could be done without difficulty, and if it be made in a solid manner, with pitching and well-broken granite, it would fall very little short of a rail-road. My only reason for keeping it distinct from the other road, is the evident injury every road sustains from horses travelling over it, and breaking up the surface; and the steam-carriages would be able to go with greater velocity, if they were not interrupted with droves of cattle: besides, it would be easy to fence it off from fifteen to twenty feet, without injury to property; and the expense of making a solid road of twelve or fifteen feet, would not be very considerable."

"Would the wear of such roads as you have described be much affected by the greater or less velocity of the steam-carriages?"—"It would be hardly affected at all, on a good road, by increased velocity; if any thing, perhaps rather less."

Mr. Johnstone, in his evidence before the House of Lords (1833) proved that "the very best pavement would cost thirteen shillings per square yard, and would cost nothing in repair for the first three years; and he gave in the following statement:—

	£.	s.	d.
First cost, per superficial yard	0	13	0
Ten years' repair, at 4*d*. per ditto . .	0	3	4
Ten years' cleansing, at 3*d*. per ditto . .	0	2	6
	0	18	10
Deduct value of old stone	0	8	0
Per yard, in 10 years . .	0	10	10

"The old stone might last 20 years longer, but at all events would be worth eight shillings per yard, after ten years wear."

Most of the London pavement appears to be laid down at an expense of seven shillings or ten shillings per yard.

"Collision" and "surface resistance" together being only $\frac{1}{100}$ of the weight to be moved, even where the surface is made of numerous stones,—the advantages of good pavement seem to be very much neglected.

The WEAR and TEAR of roads was a point to which the attention of the Select Committee of the House of Commons upon steam-carriages, in 1831, was directed. The evidence given by Mr. Telford, Mr. Macneill, Mr. M'Adam, Mr. Gurney, Mr. Farey, and myself, may be summed up shortly, that the much greater wear of horses' shoes than of carriage-wheels, proves beyond doubt, that the road upon which they travel, is more worn or destroyed by the former, than it is by the latter.

Mr. Macneill's evidence upon this branch of our subject, being most distinct, it may be well to quote it:—

"Much will depend on the manner in which the road is constructed, the materials of which it is composed, the care bestowed on its drainage, and whether it be in an open situation or shaded by trees; if the road be properly made, and in an open situation, the injury arising from the atmosphere will be little compared with the actual wear caused by the wheels of carriages and the feet of horses, probably not ten per cent. during the year; whereas on weak roads, in clay countries, every shower loosens the materials of which the road is composed, and causes considerable wear, perhaps thirty per cent., or even more, in some situations, where the road is shaded by trees. To get at something like an average proportion between the wear occasioned by horses' feet and the wheels of carriages, I have procured the following facts: the coaches which run between London and Birmingham required a hundred horses on an average, to work the up and down coach; the horses are generally shod by contract, at about 2*s.* 6*d.* per horse per month; those near London are much larger and heavier, and therefore require heavier shoes than those twenty miles out of London, and from thence to Birmingham. Near London, in the flint districts, the wear of horses' shoes is much more than it is in the quartz and limestone countries. At Stony Stratford, the weight of the four shoes of a mail and stage-coach horse averages five pounds, and when taken off at the end of about twenty-eight days, they weigh very nearly two pounds; in this period, the horses run 252 miles. At Towcester, Weedon, and Daventry, the weight of the new shoes is one pound and a half each, and when taken off weigh nearly three-fourths of a pound; the length of time which they remain on is about thirty days; this would give a wear of three pounds per horse per month; but if the greater wear near London be considered, I think it would not be too much to allow the wear equal to four pounds per horse per month, which for 100 horses for ten weeks, would give a wear of 1000 lbs. of iron. The hind wheels of the coaches are mostly four feet eight inches in diameter, and the front wheel three feet. The width of tire, I before stated, is about two inches, and when new, the thickness of the iron is three-quarters of an inch. These wheels are found to last from two to three months, according to the state of the weather, the workmanship, and quality of the iron, (about twenty years ago, they did not last seven days on an average;) suppose they now last ten weeks, in that time the tire is worn down to one-sixth of its original thickness; this would be equal to 163·4lbs., or 326·8 for both coaches; this would be to the wear of the horses' shoes, as 326·8 to 1000, or as 1 to 3-14ths nearly. Now, if the injury done to the road by the horses' feet and the wheels of carriages be estimated in the same proportion, I think it would probably be near the actual effect produced: that is to say, the injury done by the wheels of fast-coaches is, to the injury done by the horses which draw them, as one to three in round numbers. The effect produced by slow carriages and horses is different; a wagon drawn by four horses, which travels regularly from London to Daventry, at the rate of three miles an hour, is worked by fifteen horses; the wagon weighs twenty-five cwt., and carries, on an average, sixty-seven cwt.; the hind-wheels are four feet eight inches in diameter, and the front ones four feet; the breadth of the wheels is six inches; they are nearly upright, but not cylindrical; the iron tire when put on, weighs, on the fore-wheels, 285lbs,; on the hind ditto, 396lbs.; making 621lbs. When removed, the weight is, on the fore-wheels, 144lbs.; on the hind ditto, 168lbs.; making 312lbs.: wear in five months, 309lbs. The number of miles travelled in this time is 6048; the shoes that are put on the horses employed to draw this wagon weigh, when new, from two pounds and a half to three pounds each; the average of a great many gave two pounds and three-quarters, and when removed, one pound and a quarter; they last from four to six weeks, according to the weather and state of the road; but we may assume five weeks as an average, and the wear in that time for each horse, is six pounds; and for fifteen horses, for five months, it would be 360lbs. The proportion, in this case, would be as 309 to 360, or as one to 1·16, or nearly one to 1¼; on the generality of roads, therefore, I would say, the proportion of injury would be nearly as follows, when travelled by fast coaches:—

Atmospheric changes	20
Coach-wheels	20
Horses' feet that draw them . . .	60
	100

And when travelled by wagons:—

Atmospheric changes	20
Wagon-wheels	35·5
Horses' feet that draw them . . .	44·5
	100

"What is the effect of travelling by coaches and horses; whence and in what proportion does the injury or deterioration arise; the crushing of materials; their actual wear; their displacement?"—"If the wheels of carriages be properly constructed, and cylindrical, the friction, and consequently the wear, on the surface of a well-made road, will be very little, and there will be no injury from displacement of materials, except what may arise from the few surface-stones that will sometimes be started out by the feet of horses on steep hills, when they are obliged to exert a great force to draw up a heavy load. When stones are thus thrown out on a hard and solid surface, the wheels of heavy carriages will crush them, and cause an injury which would be much more than that caused by the actual wear of the wheels passing over the surface. If the road be weak or elastic, and bend or yield under the pressure of the wheels, the particles of which it is composed will move and rub against each other, or perhaps break by the action of heavy wheels over them. On such roads, I conceive the injury caused by steam-carriages will be much greater in proportion to the injury caused by light carriages drawn by horses than it will be on solid firm roads. In one instance, where an accurate experiment was made, the wear was found to be four inches of hard stone, when it was placed on a wet clay bottom, while it was not more than half an inch on a solid dry foundation (formed as described in the Report of the Select Committee on the Holyhead road, on the 30th May, 1830,) or with a pavement bottom, on a part of the same road, when it was subject to the same traffic. On the Highgate Archway road the annual wear does not appear to be more than half an inch in depth. Now as this road is very little affected by wet, in consequence of its peculiar construction," (page 196,) "and the care bestowed on its drainage, I attribute almost the whole of the diminution of materials to actual wear. On many roads, where the sides are weak, great injury arises from the crushing of materials, particularly by the action of wagon-wheels. In frosty weather, weak roads very frequently suffer more in one month than all the rest of the year. In such cases, the injury is caused by the wheels of carriages, and not by the horses' feet."

"If 30 lbs. be sufficient to move a carriage of 21 cwt. 8 lbs. on a level platform little affected by friction, and 266 lbs. be required to move the same carriage on an inclination of one in ten, the pressure in the one case being exactly the weight of the carriage, 21 cwt. 8 lbs., what would be the pressure on the road, or platform on the inclination?"—"As the pressure on the horizontal is to the pressure on the inclined plane, as the length of the plane is to its base, we have this proportion. $\sqrt{b^2+p^2}$:

$b :: W : \frac{wb}{(b^2+p^2)^{\frac{1}{2}}} =$ the pressure on the plane. In this example, w=2360. $b=10$. $p=1$, which gives $\frac{wb}{(b^2+p^2)^{\frac{1}{2}}} = \frac{2360 \times 10}{\sqrt{100+1}} = 2349.5$ lbs., or $10\frac{1}{2}$th less than the pressure on the horizontal.

"The details of various kinds of steam-carriages have been given to the committee; all act without propellers; without projection on the wheels, with cylindrical wheels; some with greater or less breadth of tire, even six inches wide; the power is applied either by crank or wheels to one or two propelling wheels, according as greater or less force may be required. Some of the experimental carriages had three, some six wheels; all will have four wheels. Some have the engines in a separate carriage, and draw the load; some carry the load and engines on one carriage. Taking the above circumstances into consideration, which would be most injurious to a road,—a stage-coach, drawn by four horses, weight of coach three tons, horses two tons, breadth of tire two inches and a half; or steam-coach, wheels four inches tire, weight four tons; in both cases velocity ten miles per hour?"—"Taking for granted that the injury which a road sustains by the wheels of carriages and the feet of horses is proportional to the wear of iron on the wheels and on the horses, and that the statement before given as to the actual wear on each be found correct, I would say, the injury done to the road by the steam-carriage weighing four tons with four-inch wheels, would be less than that occasioned by the coach weighing three tons, drawn by four horses."

"Would it be beneficial or otherwise to the roads, that steam-carriages drawing heavy weights in carriages attached to them should be substituted for wagons drawn by horses, supposing that the weight of the drawing or propelling carriage should not in any case exceed the weight of the number of horses that would have been used to draw a corresponding weight, *e. g.*

Wagon - - -	8 tons	On steam-carriage -	4 tons
Eight horses, 15 cwt. each	6 ditto	Carriage drawn - -	10 ditto
	14		14?"—

"I am of opinion, that if the steam-carriage and its accompanying carriage be constructed with wheels of a proper width, and of the same diameter as the waggon wheels, and travel with the same velocity, that the injury on well-made solid roads will not be more than that caused by the wagon and horses; in fact, if the proportion of injury before stated be correct, it will be less; but it must be recollected that weak roads suffer more than solid ones from the heavy pressure of wheels, and in such cases the steam-carriage and its tender would be more injurious."

"In descending hills, steam-carriages can regulate their velocity by reducing the action or number of revolutions of the wheels; this acts as a drag, but with the advantage to a road that the wheel moves continually round; which would be most injurious to a road, the descent of a carriage dragged as usual (not omitting the operation of the horses' feet), or the steam-carriage dragged or regulated in the mode described?"—"Not having seen a steam-carriage descending a hill in the manner described (that is, regulated by the action of the engine on the wheel), I cannot give a satisfactory answer to this question; but as far as opinion goes, I should say that the joint action of the horses and drag would be more injurious than the steam-carriage, the motion of which was regulated in the above manner, provided the wheels were of the proper width, and the total weight not greater than that of the coach and horses."

"Various local acts having passed, placing excessive tolls on steam-carriages, it may be requisite to introduce a general bill, which shall, on such roads, place steam-carriages on a fair equality (so far as their relative injury or wear of road), to common coaches on each such road; the toll on a coach on such roads may vary from one to two shillings, according to local circumstances; on a wagon in the same proportion; what standard of charge would you suggest for steam-carriages?"—"It has been stated to us, that one steam-carriage has drawn a carriage containing as many as thirty passengers, at the rate of even ten miles per hour, and nine tons weight at the rate of five miles per hour, but with smaller wheels; what regulation would you suggest as to the breadth of tire; or should tolls be chargeable in inverse proportion to the breadth of tire?"—"The toll which carriages propelled by steam, or by any other mechanical means, should be required to pay, ought, in my opinion, to be in proportion to the injury they would do to the roads, compared with that done by the present description of carriages and the horses employed to draw them, without reference to the weight or quantity of goods carried; but as I before stated, I do not believe an accurate estimate can be at present formed as to the injury that roads may sustain from steam-carriages, compared with the injury done to them by coaches drawn by horses; it may, however, I think, be safely assumed, that the injury done to a road by a steam-carriage would not be greater than that occasioned by a stage-coach drawn by horses, the weight of the engine and its load being supposed not to weigh more than the stage-coach, together with its load and horses; if this be granted, and an act passed limiting the width of wheel in a certain proportion to the weight carried, there would not be much difficulty in arranging a scale of tolls applicable to steam-carriages, which would put them on an equitable footing with carriages drawn by horses; if, for instance, a proportion, such as I have already mentioned, be adopted, viz. that a wheel should be an inch in width for every five cwt. it has to support, and a toll charged for each inch equal to the amount charged for a horse drawing in a carriage which travels with the velocity of the engine, it would, in my opinion, be a fair and equitable toll at least for some years, or until a correct proportion of injury was ascertained by experience and observation, when it might be altered or amended according to circumstances. This mode of charging toll would be extremely simple, and not likely to be misunderstood by toll-collectors, or to occasion any disputes; but there should be a heavy penalty attached to the proprietors of steam-carriages if they put a greater weight on the carriage than the wheels were intended to carry. If the engine, instead of carrying the load, draws one or more carriages after it, the toll should be collected and charged on each carriage, in a similar manner as it is charged on the engine, that is, in proportion to its wheels. An example will illustrate my meaning more clearly; suppose an engine, together with its load, to weigh nine tons, (which is about the average weight of two stage-coaches, including the weight of the horses which draw them), to pass through a toll-gate where horses drawing coaches are charged sixpence each, the toll on the two coaches would be 4*s*., and of the steam-carriage 4*s*. 6*d*. Suppose that the engine, instead of carrying the load, draws a carriage after it, and that the weight of the engine is five tons, with five-inch wheels, and of the accompanying carriage four tons, with four-inch wheels, the toll of the engine would be 2*s*. 6*d*., and of the tender 2*s*., making 4*s*. 6*d*. as before. The only objection I can see to this mode of charging toll on steam-carriages travelling over the turnpike-roads would be, that in the event of their being able to carry a greater number of passengers at a cheaper rate than the present description of carriages drawn by horses, it would lessen the amount of toll collected, as a fewer number of carriages would do the work, and many persons who drive their own horses would travel by them if found cheaper to do so; and this circumstance, although it would not affect the state of repairing in which the road was previously maintained, it might lessen the value of property invested in the different turnpike-trusts throughout the kingdom, which is a very considerable sum; but such a circumstance should not militate against an invention likely to prove beneficial to the country at large."

"Give your opinion on the probable extent of injury to roads from steam-carriages?"—"Generally speaking, I should say that the injury roads will sustain by the introduction of steam-carriages will be much less than is commonly supposed; but the actual amount of injury, or correct estimate of the comparative injury that will be done by a steam-carriage, cannot, in my opinion, be formed at present with any degree of certainty. Experience alone will decide the point. The only danger, in my mind, that is to be apprehended, is the injury which roads may sustain by the possibility of the wheel which is acted upon by the engine turning round without propelling the carriage, in which case the road would suffer considerably; and this would take place, if a train of carriages were attached to the engine, the draught of which was more than the friction or gripe of the engine-wheel on the surface of the road. As long, however, as the weight is carried by the engine, and not drawn after it, nothing of this kind will ever take place, even on our steepest hill."

"Have you communicated your conclusions on these subjects to Mr. Telford?"—"I have."

"Does he coincide with you?"—"Quite so."

"You stated, that the only propable injury to the roads from the travelling of steam-carriages would be the slipping of wheels; would it not be directly against the interest of the proprietor that the wheels should slip in any degree, there being a necessary loss of power every time they do slip?"—"Clearly so."

"From your observations of the effects produced by heavy carriages drawn by horses, in ascending and descending hills, what would be the effect under similar circumstances of a steam-carriage of a weight equal to the weight of the coach and horses?"—"I am of opinion that the effect or injury to a road would be less by the steam-carriage; for when hills exceed a certain rate of inclination, gravity overcomes the friction of the surface, and the carriages in descending press upon the horses, unless a drag be applied to one of the wheels. This, in itself, injures the road, but not so much as when no drag is used, because the horses are then obliged to bear against the carriage, and set down their feet very strongly; this often tears up the surface, particularly of weak roads. The time that is lost by the coaches in descending some of the hills between London and Birmingham, is full as much as is lost in ascending them, besides the imminent danger, even with the greatest caution on the part of the drivers. If proper springs were used, the draught would be lessened, and of course the injury to the road would be much diminished."

"On every road there are numerous six-horse wagons; you state the weight to be four tons and a half, the horses weighing four and a half more, making nine tons; should any objection be taken to a single steam-carriage of this weight, or from nine to ten tons, provided the wheels be of a proper description?"—"No; I think in the general state of roads a steam-carriage of from nine to ten tons could run with perfect safety, without injury to the roads, if it were constructed with proper wheels."

"The above question refers to a steam-carriage carrying its load; if the engine-carriage were of the weight of four tons, drawing a second carriage of the weight of six tons, thus dividing the weight over eight wheels, would the effect on the road be less injurious provided it was four and a half tire?"—" I think the injury would be less, provided the engine had the power to propel itself, and draw a carriage with six tons after it, without a slipping of its wheels."

" Carrying this principle further, if the load were divided into two carriages, each to weigh three tons, thus dividing the load over twelve wheels, would not less injury still be done?"—" Decidedly, particularly on weak roads."

" If under these circumstances you can diminish the pressure on the road by multiplying the number of wheels, should not care be taken so to frame the tolls to be levied as not to discourage the use of those steam-carriages, whose greater number of wheels could be least injurious to the roads?"—I think that would be regulated by the mode I have suggested of charging toll."

" I have seen Mr. Gurney's carriage, and examined its effects on the roads.

" I do not know the weight of the carriage, there appeared to be eight or ten people on and about it; the road on which I saw it was excessively bad, one of the worst in the country; the velocity was probably five or six miles an hour.

"There were several other loaded carriages passing along the road at the same time, and I did not remark the effect of the steam-carriage on the road to be more injurious than the other carriages.

" As far as leaving a track behind, which would have been perceived, I could not ascertain the amount of injury to be greater; it was nothing more than that done by common coaches."

Since this time Mr. Macneill has travelled by steam at higher velocities, and remains of the same opinion.

"The weight of four-horse stage-coaches varies (says the same authority) from 15¾ cwt. to 18 cwt.; most of the Birmingham day and night coaches weigh about 16 cwt. and frequently carry (the night coaches in particular) upwards of two tons of goods and passengers, exclusive of the coach; yet, taking into consideration the number of times they travel with very light loads, I should say that from two tons five cwt. to two tons ten cwt., including the carriage, would be a fair average weight during the year. The tires of the wheels are mostly two inches, but some of them are less; those constructed by Mr. Brown, and used on his patent coaches, have the edges chamfered off, so as to give a flat bearing of one inch and a half; but from the peculiar manner in which those coaches are mounted with springs, I am inclined to think the injury done to the roads by these wheels is not so great as it otherwise would be. Some coach-wheels that I have seen are rounded off, so as to form in the cross section a segment of about one inch and three quarters in diameter. The bearing in this case on the road, where the surface is hard and smooth, is reduced almost to a point, and must be extremely injurious. The coachmen remark that carriages with such wheels run wild in descending hills in summer, but heavy in winter, and when the roads are soft and muddy. The mail-coaches weigh very nearly twenty cwt. Some of them, the Holyhead coach for instance, frequently carries upwards of a ton of letters and parcels, independent of passengers and their luggage. The average weight of the whole may probably be taken at two tons. Some others, the Liverpool day mail for instance, travel very light, and probably will not average one ton and a half. The breadth of tire of mail-coaches is two inches and a quarter; the four-horse vans, which travel about six miles an hour, weigh on an average four tons and a quarter, including the carriage; the breadth of tire of one which I measured was two inches and a half, but I am not prepared to say that this is the general size of such wheels: the horses used in these carriages are of the very best and largest description, which added to so great a weight on narrow wheels, probably renders this carriage more injurious to the public roads than any other description of vehicle at present employed. There are four descriptions of wagons in general use, the eight-horse wagon, the six-horse wagon, the four-horse wagon, and the farm wagon, which is drawn sometimes by two, three, or four horses, according to the load. The eight-horse wagons, though frequently weighing, with the load, seven tons, may probably be averaged at not more than six tons the year round; the wheel is nine inches in the tire, but from a very improper plan followed in its construction, the bearing on a hard solid road is only three inches, for these wheels are generally shod with three hoops of three-inch iron, the centre one of which is of a greater diameter than the others, and projects full half an inch beyond them, which, on weak roads, such as in the neighbourhood of London, must be most injurious. I have measured one since I came to London, which travels on the Bath and Bristol road; the outer rim is conical, and can certainly never come in contact with the road surface, unless it be one on which the wheel would sink two or three inches. The six-horse wagons, with their load, generally weigh four tons and a half: their wheels are six inches wide, and of a better description than the former, though sometimes one of their hoops projects beyond the other, as in the case of the nine-inch wheel. The four-horse wagons, with their load, commonly weigh three tons and a half: their wheels are four inches wide, and are more upright than the others, and have a more level bearing on the road. The farm wagon, used in Northamptonshire, weighs on an average one ton one cwt.; the breadth of a wheel is three inches, and it carries from one ton to three tons, according to circumstances, and lasts nearly twenty years."

"On an average line of road of not less than 100 miles, on which in many places materials of very inferior description must have been used, both in its formation and subsequent repair, what is the maximum weight per wheel (say if not less than four inches width of tire) which should be carried on any kind of carriage (carriage weight included), without risk of injury to the road?"—"On a road, such as here described, the injury will be considerable by any wheel passing over it; but without a more defined statement of the quantity and quality of the materials used, I do not think this question can be answered with any degree of certainty; on all gravel roads, however made, without a foundation or bottoming, I should say the weight on a four-inch wheel should not exceed fifteen cwt., and on a wheel less than that, ten cwt. on the generality of roads, throughout the country; I do not think it would be safe to run a carriage with almost any width of wheel if the load much exceeded ten tons; in fact there are some bridges even between London and Birmingham, that it would be running a risk to pass over with a carriage weighing ten tons."

"Can you from observation say what proportion the breadth of the tire of wheels should be to the weight?"—"The breadth of tire, in proportion to the weight, will depend entirely upon the description of road over which the carriage passes; on such a road as that lately constructed by the parliamentary commissioners of the Holyhead and Liverpool roads, at the Highgate Archway, I have frequently observed wagons carrying upwards of six tons pass over it; the weight of each wheel on the road was then about thirty cwt.; and though the bearing of the wheels, from the cause I have before stated, was not more than three inches, the effect produced was imperceptible; the pressure in this case was ten cwt. on every inch, which is unquestionably too much for the generality of roads; but if we take the road from London to Shrewsbury as a criterion to judge by, I should say that a wheel ought to be an inch in width for every ton that a carriage and its load would weigh; and that if every carriage that now travels that road were limited not to exceed that proportion, the roads would be better, and maintained at a cheaper rate than at present. According to the average weight of coaches and wagons, as before stated, I have calculated the following table, showing the weight at present carried on each inch of bearing, and what I conceive might be the breadth of the different wheels if they were made cylindrical with an even bearing, and in the proportion of one inch of width for every ton, including the carriage."

Description of Carriage.	Velocity in miles per hour.	Weight, on an average, in tons.	Breadth of the Wheels, in inches.	Pressure of each Wheel, in cwts.	Pressure on each Inch, in cwts.	Breadth of Wheel, calculated in the proportion of 5 cwt. to the inch.
Mail Coach	9 to 11	2	2¼	10·0	4·40	2
Stage Coach	8 to 11	2½	2	12·5	6·25	2½
Van . .	6 to 7	4¼	2½	21·25	8·29	4¼
Wagon .	2½ to 3	6	9	25·0	2·77	6
Ditto . .	2½ to 3	4½	6	22·5	3·75	4½
Ditto . .	2½ to 3	3½	4	17·5	4·37	3½

"State your opinion as to the relative wear of a road by two carriages, both drawn by four horses, one carriage of two tons weight, with two-inch tires, the other four tons, with four-inch tires."—"My opinion is, that the wear of the roads would in each case be the same, as far as it was affected by the wheels of the carriages, probably rather less by the carriage carrying four tons, on four-inch wheels, than by the carriage carrying two tons, for four days in the week, going, on an average, 416 miles in the same period of time, and wears out 4·8 pounds of iron. If the coach-horse travel the same distance, the wear would be six-sixteenths, which exceeds the wear of the wagon-horse one thirty-sixth. In the same way might the relative injury caused by the wheels of the wagon and the coach be ascertained."

By a general substitution of steam-carriages for horse-coaches, a great saving will be effected in tolls. And wherever road trustees will go to the expense of a good tram-way of granite, or of other good hard surface, maintenance of way will be much reduced.

Iron rails for the wheels of carriages to run upon are not of modern invention. But *for purposes of general traffic they may be considered so.*

The wear and tear of such roads I have already stated (p. 200 and 201). Their saving of surface resistance, which has been seen to be their only advantage, is a mere fraction of their loss by annual maintenance.

Let us take the maintenance of way on the Liverpool and Manchester line of railway at £400 per mile, or £12,000 for 30 miles upon 250,000 tons conveyed, and this is a more favourable statement than is found in the Directors' Reports: we find that every ton conveyed along the line, has required 11 pence and $\frac{5}{10}$ of a penny for maintenance of way alone!

Let us now take the maintenance of way on the same length of granite tram-road (p. 201). It is found from five years' experience, that 250,000 tons, conveyed annually require not more than 5*l.* per mile, which, for 30 miles, would be at the rate of little more than $\frac{1}{10}$ of a penny!

Railway engineers may say that the velocity is quite different in these cases. If so, they will furnish a practical proof, that railways are, as already seen, by page 192, not free from the resistance of "collision." But let them turn and twist the case as they may, the truth will be found to stand very nearly in the following figures:—

——	Edge Railway.	Granite Tram-road.
Tractive power required to move one ton on a level - - -	10 lb.	$12\frac{5}{10}$ lb.
Annual cost for maintenance of 30 miles, along which 250,000 tons are conveyed - - -	400 *l.*	5 *l.*

So that without calculating the interest upon first cost, which for a railroad is so much more than for a granite road, there appears to be a saving, which puts edge railways out of the question. If the comparison be made between edge railways and pavement surface, where the tractive power necessary for one ton is 31lbs. and between edge railways and good turnpike roads surface where the tractive power required for one ton is 40lbs., railroads will not gain by the contrast; and yet so ardent are railroad projectors, that railway schemes are now promulgated, which will require an expenditure of thirty millions if the mania be not checked. We cannot enumerate the various lines; but point to the "Cramford and High Peak railway," as a *memento.* None of "the great commerce announced in the first account has ever passed on it for the whole distance, and no carriage whatever, except that which conveyed the committee, on their triumphant tour at its opening; all the trade having been confined to that of a little coal at the southern end."

The line between Liverpool and Manchester certainly presented a combination of circumstances more favourable than any other line of communication in the kingdom, where goods and travellers pass in both directions. Liverpool may be considered second only in commercial importance, to London; and Manchester teems with a busy and industrious manufacturing population. The productions of other countries arrive at the one, are manufactured at the other, and returned over the same line, for exportation to every quarter of the world. Such constant passage of goods demanded the best and quickest mode of inland communication; and a splendid line of railway was the consequence. How far that railway, favourably circumstanced as it is, has been profitable, cannot be gathered from the published accounts of a company. That it has not been profitable to the degree which would warrant an outlay of 1,200,000*l.* upon 31 miles of line, is sufficiently proved by the knowledge that their dividends of 8 per cent. per annum are not larger than the profits which horse coach-masters made upon the turnpike-road, even after paying a heavy duty to government; and who are beat out of the field of competition by a company, with the advantage of an immense capital, a lenient taxation, and a secure monopoly.

We will not find, however, that this corporation have had any sufficient success to warrant a payment of eight per cent.; and as this is the point of conviction with the larger portion of the community, it may be well to examine it.

The anticipated and the actual cost of construction may be compared thus:—

In December, 1825, the prospectus was published, with an estimate of cost, allowing for all possible contingencies, 510,000*l.*

In April, 1826, the estimates were sworn to, as more than amply sufficient, in the House of Lords.

In May, 1826, the first Report was issued, when the Committee informed subscribers that the work may be done for much less than 510,000*l.*, the sum estimated. In the beginning of 1829, Government advanced the Company 100,000*l.* on loan, at 3½ per cent. interest, on security of the three last instalments.

In March, 1828, a Report was issued, when the Directors state that the Railway will cost something more than estimated, but that there is no doubt that the whole will be completed out of the capital, 510,000*l.*, and the 100,000*l.* loan, in all 610,000*l.*

On the 18th of March, 1829, the Directors report that they had obtained powers, by Act of Parliament, to raise 127,500*l.* in shares, "to provide arrangements for carrying on a road proportionate to the magnitude of the anticipated traffic,—that having expended, in forming the road and works, all the first seven calls, and the 100,000*l.* borrowed from Government, they had applied to be allowed to expend the remaining three calls, on which the Government loan was secured,—that they had got one of the calls relieved, but that after consulting Mr. Telford as to the future cost of the work, which Mr. Telford reported would require much beyond the resources of the Company, Government had refused to relieve the remaining two calls. They characterised Mr. Telford's Report as "*a Document than which one more abounding with inaccuracies and erroneous statements can hardly be conceived.*"" They state, however, that they had despatched a deputation to London, when they explained "the inaccuracies in Mr. Telford's Report," and got the ninth instalment relieved.

In August, 1829, the Directors report that the work may probably be finished within the cost, and that it will not be necessary to call up the last 10 per cent., either on the road subscription of 510,000*l.* or on the carrying trade subscription of 127,500*l.* Is the Report such as to prove the gross "inaccuracies" of Mr. Telford's Report, and to justify the comments of the Committee on the conduct of that celebrated engineer? it is as follows:—

"The funds at the disposal of the Directors will be sufficient for this purpose (to form a double line of Railway between Manchester and Liverpool), without calling for the last ten per cent., either on the original capital or on the quarter shares, until it be required to provide such moving power on a large scale, as, *after ample experiment*, shall be deemed the most eligible for purposes of the Railway; and as a revenue from the carrying of passengers, and, to a certain extent, of merchandise and coal, will accrue in the mean time, it will remain for the Proprietors to determine how far the funds so derived shall be appropriated to supersede the necessity of calling for the whole of the subscribed capital. The cost of the Railway and its carrying establishments was, therefore, on 10th of August, 1829, limited to 673,750*l.*, or at the very utmost, supposing an enormous trade (ten times greater than has been realised), a sum of 735,500*l.*

In March, 1830, the Directors report that instead of 673,750*l.* sterling, they find the Railway and works will cost 820,000*l.*, in consequence, as they state, of the estimate being erroneous, and below the amount at which it had "been found practicable to execute the work."

In June, 1830, Mr. Booth, the treasurer, gives the details of how the 820,000*l.* had been, and was to be expended, as follows :—

1st, Expended till 31st May, 1830	£739,165	5	0
2d, Outstanding debts . .	7,500	0	0
3d, To be outlaid on railway, engines, wagons, warehouses, machinery, &c.	73,334	15	0
	£820,000	0	0

In March, 1831, the Directors state that they intend to raise altogether 865,000*l.*

In April, 1831, the Directors recommend the making of a new tunnel at Liverpool, which, they say, will cost 100,000*l.*, and state that thereby the omnibus establishment may be saved, and that this saving will be equal to the interest of the 100,000*l.* to be laid out; and were authorised to apply to Parliament for power to raise this sum.

In 1832, the Directors announce that they have given up omnibus establishments, but are still to proceed with the tunnel; the interest upon the cost of which was to have been paid out of the saving thus already effected. They say nothing of the capital account, but by a statement appended, it appears that instead of 820,000*l.* or 865,000*l.*, they have expended on the Railway and works, 992,054*l.* 3*s.* 6*d.*, besides outstanding and unpaid debts.

Such is a retrospect of the outlay of the Liverpool and Manchester Railway affairs, taken from their own printed reports, up till the end of the year 1831. It is now stated that the capital expenditure amounts to nearly 1,200,000*l.*

But it is my duty also to show, that there has been an error of magnitude in the calculations for the annual expense of conveying the estimated traffic on the railway.

Mr. Walker, civil engineer, and Mr. Rastrick, civil engineer, from documents handed to them by the Directors, calculated, on a regular trade of 4,000 tons of passengers and goods, cattle and coals, passing 30 miles along the railway daily, or 1,248,000 tons conveyed along the line annually, upon the 313 working days of the year, and reported that the outlay requisite to accomplish this would

be, for a speed of ten miles per hour	£90,963 14 0
Requiring an annual expenditure of	58,000 0 0
Mr. R. Stephenson and Mr. J. Locke, engineers, in the employment of the Railway Company, calculated and estimated that the same work, for a speed of 12 miles per hour, would require an outlay of only	£36,817 9 0
And an annual expenditure of only	20,307 18 0

The difference of opinion was immense, and therefore the actual amount of goods transported, and the actual cost of the transport, must now be referred to.

After three years experience of this railway, it appears that the whole amount of goods and passengers transported, only amount to about one-third of what it was calculated to be in a single year, whilst the cost of transport has been, for that fractional part, eight times greater than Mr. R. Stephenson and Mr. J. Locke calculated—

In 1831,	125,184 tons	were conveyed at an annual expense of ..	£20,062	11	0
1832,	145,914 ..		22,237	11	0
1833,	170,395 ..		27,101	4	0
Three years' traffic	441,395	Total cost ..	69,401	6	0

This amount of 441,395 tons, does not include the coals conveyed, which is but little, and cannot be easily included, as the coal owners furnish and pay for three-fourths of the locomotive power necessary for the transport of coals.

Thus the anticipated and the actual result of this famed railway, as regards outlay and current expenses, and also as regards calculated traffic and work actually done, have been strikingly different. But we must not expect such facts will be received by the public as conclusive against the general railway system. Large dividends paid by directors to shareholders will prevent their coming to such a conclusion, even although *it can be shown beyond doubt that such dividends must have been paid out of capital*, or out of borrowed money.

In January 1833, the capital invested was £1,024,375

Of which there was advanced in shares	£796,875	
And loans	227,500	
	£ 1,024,375	

The interest paid for the year was 10,522*l.* 10*s.* 6*d.*

In January 1834, the capital invested

was			£ 1,101,057	6	5
Of which there was advanced in shares			796,875	0	0
And loans, viz. as last year . .	£ 227,500	0 0			
And apparently a new loan of .	76,682	6 5			
			304,182	6	5
			£ 1,101,057	6	5

The interest paid for the year was 10,507*l.* 18*s.* 1*d.*, being a smaller interest upon a larger debt, and to be accounted for by the good credit which the Company must be in, by reason of their large dividends.

The amount of receipts and outlays are stated by the Directors' Reports to be as follows:—

———	Year 1831.	Year 1832.	Year 1833.
	£.	£.	£.
Gross receipts - -	155,502	155,808	183,305
Gross disbursements -	84,404	94,936	109,250
£.	71,098	60,872	74,055

From these sums the interest and dividends are, or ought to be, paid, but the Directors seem to borrow money for the purpose, at least we must suppose so when we find by their own accounts that, upon 30th June 1833, they ordered immediate payment of dividends to the extent of 33,864 *l.*, when the same accounts show that they had only in hand 13,332*l.* wherewith to pay them. Money was borrowed in order to do it; and this circumstance added to others of a financial nature, together with facts before adduced, lead us to the belief, that the dividends are paid from borrowed money,—that borrowed money is thrown into the capital account,—and that, in fact, dividends are thus paid out of capital.

It is difficult to say, why promoters of other rail-ways neglect the abundance of facts which they might obtain as to the working of the general rail-way system up to the present time. And it is not less difficult to find reasons, why rail-way engineers neglect the laws of motion, which are unalterable.

If I have stated these laws correctly in Chapter V., what can be more fallacious than a rail-road between London and Southampton. From London to the summit level of this proposed rail-way, there will be a mean rise of 1 in 690, upon 50 miles. By reference to Mr. Wood's table, given in appendix E, it will be seen that at a velocity of 11 miles per hour, 69 tons may be conveyed on a level, but only 52 tons can, with the same power and speed, be made to ascend this rise. From Southampton, to the summit level of the same line, there will be a mean rise of 1 in 305 upon 22 miles; and by reference to Appendix E, it will be seen that, at a velocity of 11 miles per hour, 69 tons may be conveyed on a level, but more than 40 tons cannot be made to ascend this rise with the same power and speed. Much of the loss is due to "gravitation" (pages 185 and 190); and much to the non-adhesion of the wheels to the rails, that disadvantage arising from the supposed advantage in reducing surface resistance so much. Any person who will investigate the subject, by the rules laid down in this treatise, will see that, comparing *power required* and *effect produced*, a granite tram-way would be better than an edge rail-way on a rise of 1 in 690, and that a London pavement would be much better than an edge rail-way on a rise of 1 in 305: nay, that a good turnpike road would in this comparison be nearly as good as the iron rails!

But there are considerations of even more importance than which surface will allow the greatest effect with a given power, and which will be most productive to the proprietors who supply the capital, and who are affected by the annual outlay and income. The subject has involved in it more than the interest of the few speculators, who, if they did not lose their money by a railway might lose it by some other project. Whilst a turnpike road and a granite way allow every species of carriage to travel upon them, to draw off and on, and to cross them at all places, a railway is limited to the use of wheels made on purpose, and confines the wheels to such a course, and to so smooth a surface, that they cannot be easily deflected or stopped to prevent accident to other carriages or persons travelling upon, or crossing the road. The farmer's cart, which, by the public road, may carry his produce to market, after leading it from the field, must, if to go by the railway, be unloaded or mounted on a truck. By the former that wholesome competitiou so beneficial to the community, by which the public may select their own time and conveyance, is destroyed to establish a monopoly. But, enough. I venture to affirm that a short time will see the general railway system deprecated as commercially, agriculturally, and politically hurtful.

CHAPTER VII.

CANAL CONVEYANCE.

ALMOST all the theories of the impulse and resistance of fluids, which have yet been made public, have been founded on the mathematical investigations of Sir Isaac Newton, who, instead of obtaining a perfect "solution of the problem which ascertains the motions of *three* bodies, mutually acting on each other," was obliged to rest contented with an approximation; being convinced that, where *millions* of unseen particles combine their influence, as in water, it would be in vain to expect an accurate investigation. He "figured to himself a hypothetical collection of matter, which possessed the characteristic property of fluidity." From this "hypothesis, he deduced a series of propositions, which form the basis of almost all the theories of the impulse and resistance of fluids*," since his time.

All physico-mathematical investigations have fallen short in this branch of science. Indeed, Professor Robison attempted only an "empirical theory." The difference betwixt theory and the real phenomena, being so great, that an extensiye and carefully conducted course of experiment can alone furnish us with a foundation whereon to venture a superstructure.

Too hasty assumptions of facts, or rather calculations, made from a few imperfectly observed phenomena, have, in the case of canal navigation, led men of science into labyrinths of error; one of the consequences of which has been a detrimental depression of *canal* property, on

* Robison's Mechanical Philosophy.

the one hand, and a wild and ruinous investment of capital in general *railway* communication, on the other. These circumstances make a correct investigation of the comparative merits of these two modes of inland transport essentially desirable.

In investigating *canal navigation*, it is not necessary to enter upon the mathematical discussion of the resistance of fluids. What has puzzled professors of science cannot be expected to appear in this compressed view. In further considering *railway travelling*, we shall bring the facts and the theory into close conjunction with the remarkable features presented by the Paisley canal, one of the numerous canals upon which quick passage boats are now established. Our aim is limited to the consideration of some obvious facts, by which we hope to dissipate error, and elucidate truth.

That the resistance offered by water to a boat, increases as the squares of the velocity, is a proposition resulting from a series of experiments made by a Committee of the Academy of Sciences, which consisted of the Marquis de Condorcet, M. D'Alembert, Abbé Bossut, and others, in France; and more recently confirmed by the experiment of Mr. H. R. Palmer, Mr. Barlow, Mr. Chapman, Mr. Donkin, and Mr. Bevan, on the Grand Junction canal in this country; not to mention numerous others. But the experience, for the two last years, on the Paisley and other canals, for which we are indebted to the ingenuity of Mr. Houston, of Johnston Castle, and Mr. Grahame, convinces us, that it is not the whole truth. Let us examine first the one and then the other.

Mr. Palmer's experiments, as detailed to the Committee of the House of Commons, on the Liverpool and Manchester rail-road bill, " were made by suspending," says he, " a pulley to that part of the vessel to which a hauling rope is generally attached, and making a small rope fast to the end of the towing rope; the small rope, passed over a pulley; and to the extreme of the small rope I suspended such a weight as exactly counteracted the force required to draw the vessel; supposing the resistance to be greater than was equal to the weight that was suspended, and, either the force employed, or the moving force, must move at a less rate forward. If it retained the same weight, it would of necessity rise to the pulley, or the motion must diminish the weight, and is therefore adjusted by experiment until it exactly counter-balanced the force that was employed. By these means, I got the weight which measured the resistance. At the same time I measured a space on the side of the canal, by which the velocity, per hour, was taken." These experiments were made at various velocities, and with boats of various shapes; Mr. Palmer's object being to ascertain at what velocity the moving forces, on a rail-road and on a canal, were proportioned to the quantity of goods equal to each other. "I have calculated," says he, "a table, which shows what will be the effect procured by the application of a moving force, at different velocities; and I found that, at the rate of 4 miles per hour, 1 lb. will draw upon the canal, 200 lbs.; at the rate of 3¾ miles per hour, 1 lb. will draw 243 lbs.; at the rate of 3½ miles per hour, 1 lb. will draw 299 lbs.; at 3¼ miles per hour, 373 lbs.; at 3 miles per hour, 474 lbs.; at 2¾ miles per hour, 615 lbs.; at 2½ miles per hour, 819 lbs.; at 2¼ miles per hour, 1124 lbs.; at 2 miles per hour, 1600 lbs.

Rate per Hour.	Canal Effect.	Railway.	Ratio of Effects.
4¼	180	180	1 to 1
4	200	180	1·11 — 1
3¾	243	180	1·35 — 1
3½	299	180	1·66 — 1
3¼	373	180	2·07 — 1
3	474	180	2·63 — 1
2¾	615	180	3·42 — 1
2½	819	180	4·55 — 1
2¼	1124	180	6·24 — 1
2	1600	180	8·88 — 1

So that it appears, that $2\frac{1}{4}$ miles per hour, is 4·55 to 1, that being the rate at which horses usually walk, when they produce the most effect; it is the rate at which the comparison should be estimated, provided horses are used."

Four miles and a half per hour seemed to Mr. Palmer to " be about the greatest speed at which a vessel ought to be moved, under these circumstances; *otherwise the boats would have driven the water out of the canal.*"

It must be particularly observed, that all these experiments were made with the boat *immersed* in the water; and the theory supposes, that the transverse section of the part of the boat in the water, remains the same, at the different speeds. But the facts, on the Paisley canal, published by Mr. Grahame, and mentioned below, were obtained when the boat was *skimming* the surface; and the theory supposes, that the transverse section of the part immersed is lessened, in consequence of the boat's great velocity. Before going into a detail of the latter facts, we shall examine some phenomena, exhibited in the daily occurrences of life, and bring them to bear on our subject. In so doing we shall consider, first, a horizontal motion, obtained with a body on the surface of water, *before im*mersion, with the force causing it to *immerse;* and then such a horizontal motion, obtained *after immersion*, with the mode by which the body may be caused to *emerge.*

A body descending perpendicularly, with a force of 16 feet per second, upon a sheet of weak ice, will be precipitated to the bottom. The ice is not strong enough to bear it. But, if just before the falling body touches the ice, its perpendicular force of gravitation, G, be compounded with a horizontal force, H, of the same intensity, the compound force, R*, resulting, will not break the ice.

* The fundamental theorem is this :—Two uniform motions in the

The stone will come into contact with the ice at an angle of 45o. The ice will prevent the body sinking, and the body will consequently slide along the ice with so much the greater velocity; and if this velocity be kept up, it is certain the ice will not be broken. But, we suppose, if the force, H, should cease, and the body be left resting on the thin ice, its weight, or gravity, G, would break through, and take it to the bottom of the pond. This we see exemplified when a stone, which, if let fall perpendicularly with a force of 12, would break the ice, is deflected by a horizontal blow of 12; it alights on the ice at an angle of 45°, with a force of about 17, which, not being perpendicular, will not break the ice, whilst the increase of force will tend to carry the stone farther along the ice. If the stone penetrate the ice, we must take into our calculation the resistance of the water, when we seek for the direction it must take, and the intensity of the compound force. We therefore suppose it does not penetrate at all. By which supposition we avoid the difficulty involved in the resistance to bodies moving in water; and although we have the resistance of the air above the ice, we do not consider that this calculation can be materially affected by our throwing it entirely out of the account.

Let us now suppose the water not to be covered by any film of ice, but perfectly smooth; and that a sphere of half the specific gravity of water were to fall on the surface, with a force, G, a sudden shock would be given to the spherical body: it would pause before it penetrated. This we know by smartly slapping a surface of water with our hand, when the shock is felt through the whole arm: also by leaping into the water, whilst bathing, in such

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sides of a parallelogram, compose a uniform motion in the diagonal. The velocity, R, in the diagonal, is to the velocity in either of the sides, G or H, as the diagonal is to that side.

a way as to meet the surface with face, abdomen and toes, at the same instant, when the blow on the stomach often produces sickness. This shock, or blow, or pause, is occasioned by the difficulty of displacing the water (not to enter upon considerations of films of air, or elasticity of water*), which requires a little time to do. If then this sphere, *before settling* in the water, be pulled or impelled by a horizontal force, it will be prevented from settling; just in proportion to the degree in which that horizontal force lessens the force of the sphere's tendency to assume the depth, assigned by the law of gravitation. The transverse section of the part, immersed, will be so much less, in this case, than it would have been if the demand of gravitation had been answered. Hence, less horizontal power will be required than when the body has fairly settled. We will speak of the economy of *speed* hereafter. Meantime, we must bear in mind, that if we do not keep up the velocity, the body will sink deeper, and require more power. The gravitation, G, must never much exceed the horizontal impulse, H; or it will prevail to sink the body.

Facts will be detailed, as we proceed, showing, that if the resultant of H and G be not equal to propel a canal boat about 12½ feet per second (8½ miles per hour), G will prevail; and then the resistance of the fluid, to the boat *immersed*, will be *as the squares of the velocity.* If, however, R be equal to occasion a velocity of 16 feet per second (11 miles per hour), and be applied before the body has been caused to settle in the water, the body will be carried along, near the surface, whilst the water acts as a support and lubrication for it. This we see when boys play at their game of "duck and drake."

* The density of a body is no proof of its non-elasticity. For instance, the diamond, though hard, is one of the most elastic substances we know.

Again, in a case where the specific gravity of the body is greater than water. We see a boy throw a thin stone along the surface of a pond. The stone proceeds by a succession of bounds; each successive bound being less than the former one, H, is reduced in intensity; at length we see a few short skips; H has diminished so much that G prevails; the resistance of the water is overcome by the stone's longer continuance at that spot, and it sinks.

If it be said that the film of air betwixt the stone and the water line is so much greater than it is under a sphere of equal density, we will adduce our experience with a *rifle* ball, which bounded laterally from the wall-side of a breaker, to a distance of 30 yards on the beach, endangering the life of a passer by. The spinning motion of this ball upon its axis, and its mere tangental contact, would very much prevent such elastic film of air. We will adduce, also, the action of shot from a ship's gun, bounding along in a manner like the stone above described, and which enables the gunner to use the ship's lee side guns, even when too much depressed, to be pointed at the enemy. It is true the flight of a cannon ball is, say (here), 900 feet per second, whilst the velocity of the stone may not be more than 16 feet per second. At each successive bound, however, the shot goes slower; and ere it sinks under a smooth sea, its speed is so much decreased that we could easily measure it. For the purposes of naval architecture, an exact measurement of the last bound of bodies, varying in shapes and densities, would be of great importance, and would furnish a very valuable table of data; and such could be most accurately made at some of the arsenals.

A duck furnishes us with another illustration. She appears to have a difficulty in settling in the water after her flight. Her wings are clapped close to her side, and she skims along, deepening as her projectile force is decreased. The cause of there being resistance to the horizontal motion of a body, entirely immersed in water, arises out of the circumstance of the water having to be divided, and the particles to be moved or thrown aside (not to mention other causes). When we attempt to plunge a body into water, we meet the same resistance. In both cases, force must be employed for putting the contiguous fluid in motion to displace it. And whether such displacement be at the belly and chest of a duck, at the lower part of a sphere, or at the prow of a deeply laden barge, it must, in each case, be accomplished by force.

Having discussed the resistance which obstructs *im*mersion, let us proceed to consider the resisting force which obstructs *em*ersion.

A fluid, as defined by Professor Robison, is "a system of small bodies, or a collection of particles, similarly or symmetrically arranged, the centres of each being situated in the angles of regular solids." When we attempt to haul a boat, floating among these, force must be employed; not merely to move the boat from a state of rest, but also to move the particles of the contiguous fluid from a quiescent state. For the communication of power, force, or motion, *time* is absolutely necessary; and if many particles are to be put into motion, a *proportionate space of time* must elapse; so that not only the particles in immediate contact with the boat, require time to be put in motion, but the surrounding particles also are acted upon. Now, from a fact mentioned by Mr. Grahame, that "the approach of a *slow* coal boat is perceptible" on the canal, "a surface mile and upwards, before it comes forward," we may easily imagine how much valuable power must be lost in putting particles in motion, which had better have been saved. Cannon balls, spread out in a single tier, upon an even level surface, each ball being in close contact with its neighbouring balls, furnish us with an illustration. If to one, in the centre of the tier, we fasten a cord, and haul upon it, from a point a very little above it, and at a distance, very *slowly*, the motion will be communicated to the other balls, in its way, and they will all be more or less displaced. This would be doing more than we intended, and, at the same time, a waste of power. It is a fixed principle, that every action of a body on others is accompanied by an equal and contrary re-action. If then, by a quicker tug of the cord, we do not allow the ball to communicate motion (or much motion) to the contiguous balls, the power, which would have been lost in overcoming the re-action (*i. e.* moving the contiguous balls), is husbanded in the cord; the individual ball is acted upon and must obey the law of force. It chooses the place of the least resistance for its escape, and rises over the circumjacent balls. Had the bodies, from which it emerged, been like particles of water, they would have helped it up by their hydrostatical pressure, filling up behind the ball as it rose. In the heaving of the lead we have another instance. Whilst the seaman, in the chains, is coiling the line for another heave, the ship making good way, the lead seems to float on the water. A particle of water at the surface of a canal would, we apprehend, be acted on in a similar manner; and a body of water *en masse*, say a piece of ice, would, in a similar manner, be raised above the surrounding particles of fluid. The persons who collect ice for ice-houses are practically acquainted with this; for they, by a smart tug or push, often make a sheet of ice skip on to the side of the pond, or on to the solid field of ice. It may, therefore, be safely concluded, that a canal boat will be acted on in a similar manner; particularly with a bow constructed so as to help it to emerge. This, however, rests not upon calculation and speculation. The facts of three years' experience are, to many, well known; and we have some of them before us in a printed letter, addressed by Mr. Thomas Grahame to the proprietors and traders on the canals, in the line of the projected railway betwixt London and Birmingham. The facts therein detailed are so apt to our purpose, so consonant with laws, which we have above investigated, and of such importance, that we shall quote pretty fully.

"Two horses on the Paisley canal boats, drag, with ease, a passage boat, with her complement of *seventy-five or ninety passengers, at the rate of ten miles an hour*, along the canal.

"The facts now stated, though more decidedly exhibited in the Paisley canal, from its narrowness, have been proved and exhibited on various other canals, and must, though in different degrees, affect motion along all bodies of water.

"I have been dragged, by one horse, in a common gig boat, with five or six other persons, for two miles, along a canal, at the rate of fifteen miles per hour; and this speed was not limited *by the labour* of the draught, but by the *power of speed* of the horse. A high degree of speed is safer both for the light boat and the canal works, than a speed of five miles an hour with a common heavy boat; as the light boat carries little way, or momentum, and might be dragged at the above high velocity to the very entry of a lock, and would have her speed reduced before she was fully into it, so that there is no danger to the gates.

"I have also performed a voyage of 56 miles, along two canals, including the descent of four, and the ascent of eleven locks, the passage of eighteen draw-bridges where the line was thrown off, and sixty common bridges, and a tunnel half a mile long, in six hours, thirty-eight minutes. The boat was of a twin shape, 69 feet long and 9 feet broad, and was drawn in stages by two horses each stage, and carried thirty-three passengers with their luggage and attendants."

The evidence before the Committee of the House of Commons has been shown. At that time the *higher velocities had never been tried,* and the railways were consequently very generally considered far superior to canals. Rail-road projectors exulted in what they considered a physical advantage over water communication. For more than seven years we have had railway schemes thickening upon us; not confined to one traffic or another, but proposed for all situations, up hill and down: nay, after having gamboled in their visions over the united kingdom, the projectors are now not afraid to come even to the very banks of Father Thames and propose to rival him by their railway to Dover! "A speed of ten miles an hour," says Mr. Grahame, "has for the last two years been maintained, in the carriage of passengers on one of the *narrowest, shallowest,* and *most curved canals in Scotland,*" "where the vessel carried upwards of 100 passengers, *or as many as are carried in a train of coaches on the Liverpool and Manchester Railway.*

"The *expenses or cost* of obtaining *this speed* are so trifling, that the *fares per mile are in these quick boats* just *one-half* and *one-third* of the *fares in the Liverpool Railway coaches,* while at these low fares the profits are such as have induced the boat proprietors *to quadruple the number of boats on the canal.*

"The *ordinary speed* for the conveyance of passengers on the Ardrossan Canal has, for nearly two years, been *from nine to ten miles an hour,* and *although there are fourteen journeys along the canal per day at this rapid speed, the banks of the canal have sustained no injury.*" "The boats are formed 70 feet in length, about 5 feet 6 inches broad; and, but for the extreme narrowness of the canal, might be made broader. They carry easily from seventy to eighty passengers, and when required, can, and have carried, upwards of 110 passengers. The entire cost of a boat and fittings up, is about £125. The hulls are formed of light iron plates (16 gauge), and iron ribs, and the covering is of wood and light oiled cloth. They are more airy, light, and comfortable than any coach; they permit the passengers to move about from the outer to the inner cabin; and the fares per mile are *one penny* in the *first*, and *three farthings* in the *second cabin*. The *passengers are all carried under one cover*, having the privilege also of an uncovered space. These boats are drawn by two horses (the prices of which may be from £50 to £60 per pair), in stages of four miles in length, which are done in from 22 to 25 minutes, including stoppages to let out and take in passengers; each set of horses doing three or four stages alternately each day!

"The entire amount of the whole expenses of attendants and horses, and of running one of these boats four trips of 12 miles each (the length of the canal), or 48 miles daily, including interest on the capital, and *twenty per cent.* laid aside annually for replacement of the boats, or loss on the capital therein invested, and a considerable sum laid aside for accidents and replacement of the horses, is 700*l.* some odd shillings; or taking the number of working days to be 312 annually, something under 2*l.* 4*s.* 3*d.* per day, or about 11*d.* per mile. The actual cost of carrying from 80 to 100 persons a distance of 30 miles (the length of the Liverpool railway), at a velocity of nearly 10 miles an hour, on the Paisley Canal, is therefore just 1*l.* 7*s.* 6*d.* sterling." Whilst the daily expense of the railway is much more than three times as great!"

Such facts rest not on the evidence of a few engineers merely. From the very best sources of information we are favoured with many particulars to the same effect.

"The Paisley or Ardrossan Canal," says the private letter of a scientific friend, "commences at Port Eglington in the immediate neighbourhood of Glasgow; from which place the fly-boats start at stated periods of the day. The distance to Paisley is eight miles, which was gone over in 55 minutes; the boat which performed this trip was one of the regular passage boats, and going at its ordinary speed; the number of passengers was 35, but there appeared space enough for twice as many, with comfort. This boat measured 75 feet from stem to stern, and about 5½ feet breadth of beam; constructed of plate iron; the interior neatly fitted up in every way, and provided with a handsome awning to protect the passengers from the weather.

"We returned in another boat of nearly the same dimensions and construction, the same distance, 8 miles, in 51 minutes. The complement of this boat was 84 passengers. We were told it had carried 100 upon an occasion.

"Two horses are found sufficient (with relays) for tracking at the speed above stated; but they canter along the towing path with the greatest apparent ease.

"It is to be observed, that the Paisley Canal is both narrow and crooked; probably as much so as any in the country; and consequently these attempts must be considered as made under the least favourable circumstances. They have notwithstanding succeeded, to the fulfilment of the sanguine expectation of their projectors; evinced by the decided patronage of the public, and increase in number of the passage boats.

"It has been erroneously stated, that no surge is caused on the canal bank. At the wide part of the Glasgow extremity, it is true, the motion is only indicated by a slight ripple on the bank; but in passing the bridges, where the water surface is very narrow, the rapid displacement of water (as might be expected) occasions a wave, sufficient to overflow the towing path.

"This, however, cannot form any obstacle to the adoption of high velocities in canal navigation; as in those places where the canal was of an ordinary width the attendant ripple certainly did not exceed that of a common fly-boat at four miles an hour.

"I may add, that the fare charged for the trip between Paisley and Glasgow was for steerage passengers 6*d.*; those sitting further aft paid 9*d.*"

Improved light iron passage-boats are now established on the Paisley Canal, Union Canal, Forth and Clyde Canal, in Scotland; and on the Preston, Lancaster, and Kendal Canal, in England; all travelling at speeds varying from 9 to 10 miles per hour.

The minutes of conversation at the Institution of Civil Engineers, also, furnish abundance of proof of a similar nature.

It is not possible that Dr. Lardner could have known these facts, or he would not have said, that "the effect alluded to would not be produced, if the boat were propelled by a steam engine *in it;*" nor is it possible, we think, that *Edinburgh* Reviewers (only 45 miles from the scene) could have known them, or they would not have "ventured," as in their number for October, 1832, they do, "to affirm, that a similar result would not be found to attend the propulsion of a boat, by a steam-engine acting on paddle wheels." Now, with all respect for the former opinion, proceeding as it does from one of the most eminent literary men of the day, coupled with his belief, that such facts are, "in some degree, dependent on the peculiar mode in which the boat is drawn, by the power acting on the banks;" and, with all deference to the opinion of the latter, we without hesitation or qualification, pronounce them both to be wrong *in toto.*

A cannon ball has force *in it,* and as has been explained, does the *very* thing the one writer assumed "would not be produced," and without being in any "degree dependent" on the power supposed. All water-fowl having power *in them,* acting, "by *paddles,*" produce the very result which the Reviewers "ventured to affirm" they would not produce. When a duck, swimming leisurely on a pond, is stimulated by a piece of bread, thrown a little way before her, she *rises* on the water *without using her wings,* and by propulsion arrives at the object. This obtained, she settles again in the water to that line, which gravity assigns her. A ball, fired from a gun in such manner that the diameter of the ball is at the surface line of the water, will *rise* to the surface; and when its projectile power is exhausted, it will heap up a wave before it; the hydrostatical pressure of which, and gravity,—forces now more strongly acting on a body immersed,—will stop it, and send it to the bottom. These effects, which are witnessed at the starting and stopping, are the same in kind, whether we take the case of a duck, of a round shot, or of a boat. They differ only in degree, varied by difference of density and shape.

After travelling many hundred miles on canals—not a few of them, in the late Mr. David Gordon's (my father) steam-boat—and after a practical acquaintance with most of the facts above stated, I maintain that a steam engine *can* propel a canal boat at these high velocities. Indeed, if Dr. Lardner and the Edinburgh Reviewers fairly, and without bias, look into the subject, as we doubt not they will do, they cannot fail to see that it must be so. To maintain the contrary, is to contradict the doctrine of Dynamics, which the one inculcates, and which neither can subvert.

Mr. Robison, Secretary to the Royal Society of Edinburgh, made experiments upon the Forth and Clyde Canal, in order to ascertain the best forms of boats for canals; the results will be found in the "Transactions of the Society of Arts, 1833." We would refer readers to that paper, and also to an excellent work by Mr. Macneill, "On the Resistance of Water to the Passage of Boats upon Canals and other bodies of water*."

Mr. Macneill's experiments were conducted with that patient industry and mathematical accuracy for which he is so well qualified. Having myself assisted in all the experiments which he has published, I may be permitted to sum up his results as follows:—

There was no reason to doubt the accuracy of the law, that the resistance increased as the squares of the velocity *when the transverse section immersed remained the same.* But in a range of velocities from 1 to 12·396 miles per hour with an iron passage-boat, such as is used on the Scotch canals; and in a range of velocities from 1 to 14 miles per hour with various shaped models; the resistance was *not* found to be as the squares of the velocities when the boat was hauled at and above 6 *miles per hour.*

At the velocity 10.383 miles per hour, the iron passage boat, containing 15 persons, and weighing in all 3·5 tons, was hauled by two horses, whose exertion, registered by Mr. Macneill's dynamometer, was 285·15 lbs.; whereas if the old law, of the resistance being as the squares, had been correct, 429.5 lbs. would have been necessary. We afterwards measured the boat's *emergence* from the water, and although it could not be stated with mathematical accuracy, there was no room left for doubting, that the emergence of the boat caused the difference.

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* Published by Roake and Varty, London.

Without going into detail, we must notice the different position in which canal property now stands, by this relief or escape from the old law, of the resistance being in the duplicate ratio of the velocity. The expense of horse power does not appear so extravagant at the higher velocities, of nine and ten miles per hour, now rapidly resorting to upon canals; and "it is now sufficient to state, that by Mr. Wood's formulæ, and according to his table, page 458, where he gives a comparison between the effects of horse power, when drawing on canals and on railways, it would require 193 horses to draw 480 tons over one mile in a day, at the rate of 10 miles an hour, or 2·4 tons over one mile by one horse: and that by Mr. Tredgold's table, page 169, he states that the useful effect which a horse can produce in one day at the velocity of ten miles per hour, is 6.6 tons. Now the average number of passengers carried in the light boats between Glasgow and Johnston, may be fairly taken at 45, or about 3 tons; and the boats are drawn by two horses at the full velocity of 10 miles per hour, the horses travelling 12 miles a day, at four different intervals of time. This is equivalent to 36 tons drawn over one mile by two horses, or 18 tons by one horse each day." Here, then, horses are daily doing 270 *per cent. more* than Mr. Tredgold calculated upon, and 750 *per cent.* more than Mr. Wood calculated upon. Many railway calculations have been made upon the authority of these writers, but in this particular they are so enormously out of the truth, that we must look for bitter disappointment to the proprietors of such shares.

CHAPTER VIII.

DIFFICULTIES, DELAYS, AND REMEDIES.

THAT so many of the attempts at locomotion upon the turnpike-road, as we have examined in Chapters V. and VI., should have proved abortive, and that so few should have been successful, is no wonder, when it is remembered that almost every patentee or steam-carriage projector has endeavoured to work independently of his contemporaries in the same field. If one has had an improvement in the boiler, he has refused to look at another's experience in general arrangement. If this inventor has improved the mode of propulsion, he lightly esteems the advantage of that one who has arranged a regular draught for the fire. A disposition to work independently has been the ruin of numerous hopes, and the sickener of those whose funds were for a time at their disposal. Who can look at the various attempts above-mentioned,—and they are, perhaps, but a tithe of what in the hands of another author might have been given, —and deny the truth of the above observation? There are to be seen the names of distinguished mechanics, of acknowledged philosophers, and of eminent engine-builders—all falling short of Mr. Gurney, Mr. Hancock, and Colonel Macerone. Many of them have exhibited beauty of arrangement in minor details, but nothing more; and, the public mind being always impressed by the majority, the labours of such men have encouraged the belief that there are insurmountable physical difficulties which still remain. That there are physical difficulties no one ought to doubt, but that such are to be overcome is best proved by the facts already adduced. That successful builders will detail their process for doing so, we cannot expect; building may be their business hereafter, and their hard apprenticeship will but little dispose them to publish all the secrets of their craft. Still they may be arrived at by observation; and for myself I must acknowledge, I have been in the most handsome manner instructed by them, and permitted the walk of their factories. The abuse, not the use, of their experience being what they are most disposed to prevent.

On Plate I. (the Frontispiece) there will be found the plans of several inventors, which I have endeavoured to blend together, and from which a steam-drag might be constructed.

When steam conveyance becomes the regular means of inland communication, we may expect the public to prefer travelling by a distinct carriage attached to the steamer, and to seek for the greatest expedition which may be maintained with safety and economy. The owners of such conveyance, who know that the mail coaches carry only seven passengers, and are as profitable to the contractors as any other species of conveyance, will most likely see that they can more readily provide for facility of management by light steam-drags, to which a pair-wheeled carriage may be attached for conveyance of six or seven passengers; and as a drag can be used for posting, the whole of his *steam carriages* may be of one size and pattern, which is a matter of great moment where repairs are requisite. There may be slight difference amongst them in the arrangement of the engines or boiler, but these differences should in the first instance not be such as to render any thing more than a partial change necessary. An abandonment of the whole should be avoided.

The principal difficulties present themselves in the boiler, the fire-bars, the pumps, and the crank.

Whatever boiler be intended, should be so situated as to be easily removable and easily replaced by another of the same or superior description. The boiler-case should also be arranged with a view to change. Screw-bolts and nuts for the latter, and couplings for the former, being provided for such purpose: by this arrangement the engines, wheels, tanks, and carriage, would remain as before such change. The posterior part of the steamer has been found the best for the site of the boiler. The frontispiece is drawn without a boiler, but the situation for it may be seen at A A.

Safety is absolutely necessary, and as has been shown in Chap. IV., an explosion cannot be with certainty avoided; therefore provision should be made, that when a boiler does burst no damage may be done. This provision is as yet only obtainable by the use of small chambered or tubular boilers. Mr. Hancock's boiler (p. 135) has been preferred by some, and Mr. Farey in his evidence (p. 145) prefers it to Mr. Gurney's arrangement of tubes. It is but fair to Mr. Gurney, however, to state that Mr. Farey had not then seen Mr. Gurney's boiler for two or three years. There is moreover a distinguishing feature in Gurney's, to which much of its philosophical beauty is owing. This is the chambers (K K fig. 5, and E fig. 6 and 7, plate XI.) which he calls separators, wherein the water blown forward out of the tubes, is allowed to subside and return to the lower chambers, so that steam may be obtained in a dry and pure state for use. When Sir Charles Dance and Mr. Field adopted the arrangement fig. 10, plate XI., they neglected the use of separators, as did Mr. Gurney's agent in Paris, some years before (see p. 147). Without them much water is liable to be blown into the engine-cylinders; indeed I am convinced that the want of "power" in the steam trip to Stoney Stratford (p. 96) is fairly attributable to want of dry steam. I have signed the Report wherein that party of engineers say "the size of the engine was not sufficient to carry so great a weight along so heavy a road at any high velocity." I am now, however, inclined to think the engine might have done all the work requisite, if she had been supplied with *dry* steam. I will illustrate this shortly by a bottle of soda water, which, when the cork is drawn, rushes out in an instant by reason of the relief of pressure, which permits the carbonic acid (gas) to escape from innumerable points at the interior, as well as at the sides of the liquid: these æriform particles are in solution with water, and cannot escape without hurrying the liquid with them, and the bottle is often left empty, although the neck may never have been reversed. Similar to this, is the action of water and steam, when highly heated and under pressure, the steam being in solution; a release of pressure allows steam to form from every particle of water, in the small tubes or other small compartments, and the water is hurried along with it, into the engines, to their great disadvantage. It will be obvious that such action must be increased by high degrees of temperature and pressure, particularly where the throttle-valve, which regulates the supply of steam to the engines, is opened for giving more steam at a difficult part of a road. The greater the difficulty of the road the more likely is this evil to present itself, unless a good system of separation be adopted. The boiler, fig. 10, plate XI., was the one in use on the occasion alluded to in Chapter III. (p. 95), and no other reason than the one just assigned, can be satisfactorily given for the expenditure of water which I observed on that journey. On this account, and for reasons before given (in pages 140, 146), I recommend Mr. Gurney's boiler with the separators. It is in my opinion the safest, lightest, and most philosophical yet made public.

When a more perfect boiler is published, the arrangement of carriage proposed on the frontispiece will allow of its substitution without any other alteration being required.

The fire-bars, or the tubes upon which the fire is laid, must be well attended to, and clinkers must be well knocked off. Mr. Hancock has recently obtained a patent for a method of pushing out the hot bars from under the fire, at the end of his stages, whilst he pushes in a cool and clean set of bars in their stead, without spoiling the fire; and by this means he saves the time he would otherwise lose in knocking off clinkers. Where bars are used, this is a good arrangement, and if to it be added a means for taking away the bars suddenly, and of allowing the fire to drop instantly from under the boiler, as has been done by Mr. Palmer, (p. 158), there would be considerable advantage when a sudden removal of the fire is desirable.

When the fire is laid upon hollow tubes, through which water circulates, this arrangement for shifting is not so necessary. A good fire-man may keep his fire bright: still he must spend much time in hunting for, and removing the clinkers.

The formation of clinkers, and the stoppage of air through the fire for the support of combustion, is the cause of a steam carriage's power falling off after a run of three or four hours.

The blast, or draft of air through the fire, will be impeded by clinkers if they be allowed to form.

Mr. Hancock blows the fire with a current of air, produced by a fanner, which is turned rapidly round by the engines, and therefore he requires no tall chimney to produce a draft. Mr. Gurney formerly used a fanner to blow the fire, and also a chimney of some height; but he has lately laid it aside, and adopted the plan of carrying the waste steam, which has passed through the engines into a blowing box, as it is termed, which consists of a cylindrical chamber, 20 or 30 inches long, and 7 in diameter; in the centre of which, through a spiral pipe, cold water from the feed-pump to the boiler passes, and absorbs some heat from the waste steam; from thence it passes to the bottom of the upright chimney, and there discharging that steam, through numerous contracted orifices, in vertical jets, which, by rising upwards with great velocity in the centre of the chimney tube, gives a vast increase to the draft of heated air and smoke in the chimney tube, without any great height being necessary; and this plan occasions a most active current of fresh air to pass up through the fire, and urge the combustion. This is a most important improvement in locomotive engines. It has been introduced by Mr. Stephenson into his engines on the Liverpool and Manchester Railway.

"The waste steam (says Mr. Farey) was very commonly discharged into the bottom of the chimney, in Trevethick's high-pressure engines, many years ago, in order to mix with the smoke ascending in the chimney, and thus the waste steam was got rid of: it improved the draft in that way, by rendering the smoke more buoyant, but only in a slight degree; but the waste steam was not discharged through a contracted orifice to give it velocity, nor was it directed upwards as is now done by Mr. Stephenson; and that vertical jet of steam in the centre of the chimney gives such an intensity of draught through the fire as was never procured before, and with the further advantage that the rapidity of draft so produced increases whenever the engines work faster.

The blowing-box just mentioned is always under some pressure, because a valve is loaded, and must be lifted ere the steam can pass off to the chimney. Thus the valve being loaded to 3 lb. per square inch, the engines have to blow off against a pressure of 15 lb. + 3 lb. (see p. 21), instead of only 15 lb.; and it must be ascertained whether such an arrangement, or that of a revolving fan, requires most expenditure of power.

The condensation of waste steam, so as to return it again to the boiler, is a desideratum which, when obtained, will determine the use of a blower: the steam need not then be destroyed in the chimney, as at present it must be, to prevent the cloud of vapour which would otherwise attend a steamer. The waste steam could not then be spared as a means for creating a draft.

In 1828, I proposed as a question to the Institution of Engineers: "Cannot the water from the condensed steam be returned into the boiler of marine engines without admixture with the condensing water, and thus prevent the formation of salt in the boiler?" Considerable discussion took place upon the subject. It was allowed, that for small engines it could be done, but that for large marine engines such an arrangement had not at that time been successfully adopted. An engine under my care had been worked, and the condensed steam was reduced in temperature to 110°, which we pumped back to prevent a deposit of fur from new supplies of cold water. The loss of water by leakage was made up by pumping in about one-sixth of cold water.

On plate XIII. are views of this condenser. Fig 4, is a view with one side with the outside casing off. Fig. 5, is a view of the tubes made of thin copper. Fig. 6, is an external view; and fig. 7, is a plan of the tubes. The waste steam was blown down through the interior of these thin copper tubes, whilst cold water was pumped up around them. Condensation was complete, and no steam blew off. In steam carriages, however, cooling water could not be afforded; but I have seen a condenser which my father made of similar thin tubes, cased with hair-cloth. Sufficient cold was produced by a strong blast of air amongst the hair-clothed tubes. A little water, dropping on the cloth, and keeping it moist, caused evaporation and cold sufficient to condense the steam. A steam-carriage may, at least, save some heat from the waste steam, and also save some water room, in her tanks. The point for experiment is the economy. On plate I., I have drawn no fanner or other blast, because I believe the steam draft (p. 254) is the best arrangement hitherto tried.

No good arrangement has yet been made for keeping the water in the boiler constantly at the same level. If some infallible mode were introduced, it would be of the utmost importance, where variation of height in the water level is so essential, as it ever must be in a boiler of small capacity. The best arrangement yet devised, has been that exhibited in fig. 14, which was introduced in 1825 by an American gentleman. A is a revolving cup, made like a cock; in its revolution, the cup being filled in the water-cistern B, offers it to the boiler C, taking round with it the cup full of steam, which again escapes into the tank B. This was good for keeping the water level accurately, but the disadvantage attendant upon the loss of steam which escaped into B, was very great.

The pumps, plate I., C C, require very accurate workmanship. They are the source of many failures, where boilers of small water capacity are used. They must be so situated that the engine-man can get easily at them, and they should always be below the tank, that the suction-valves may more easily act.

The tank and frame should be one; lightness and strength may thus be united. In the middle of the tank a space should be left, as on plate I., fig. 2, for the engines.

The engines may be either two reciprocating engines, or two rotatory engines, described in Chapter II. On fig. 2, I have drawn one rotatory engine. Fig. 3 is a pair of reciprocating engines which vibrate on trunnions, and in such manner, that motion from the piston rod is communicated directly (*i. e.* without the intervention of the connecting rod H, plate II.) to the crank. Such an engine can be placed in the same tank frame (fig. 2), if it be desirable to remove the rotatory engines. Fig. 4 is a side view of the vibrating engines.

The rotatory engine of Earl Dundonald has been described at pages 23 and 24; but since they went to press, I have been permitted to copy a drawing of a new single engine, with two pistons, which I have on several occasions seen at work in the most satisfactory manner. On fig. 2, (Plate I.), there is seen the view of such an engine when looked down upon. On fig. 1, the external view of one end of it is seen. Fig. 5 is a section showing the two pistons. Fig. 6 is a section in direction of the axis, showing the same parts (but in a different view) as are seen in fig. 5. Readers who have examined the account given in Chapter II., of the first modification of this engine, will easily trace the movement of this improved arrangement: A, being the induction, and B, being the eduction ports and passages.

The crank shaft of the engine should not be made on the hinder axletree, as in Gurney's carriage. Here Hancock's arrangement of two shives and an endless chain (p. 108) should be used. Fig. 7, plate I., exhibits an arrangement of wheels, which Mr. Gurney now proposes to use. He has abandoned the plan of working with the hinder axletree cranked, but prefers toothed wheels to the endless chain of Mr. Hancock.

Wheels of great strength are necessary. Mr. Hancock has used wooden wheels, made after a plan of his own. On plate XIII., fig. 17, is a front view of a wheel, with the front bindplate removed, to show the meeting of the wedged spokes, which are of straight-grained well-seasoned ash, tennoned into the felloes as in common wheels, but the nave ends are very accurately fitted to each other in radial joints, butting against the iron box of the axle, and forming around it, to the circumference of the bindplate (shown by a dotted circle), a solid connexion of timber.

Fig. 18, is a horizontal central section of the above. The tire is secured by a bolt and nut, or rivets, through each felloe, the heads being countersunk, so as to stand flush with the outside of the tire. The box, which contains a reservoir for oil, is formed with its flange in one casting, the outside diameter of the flange being the same as that of the front bindplate, which is like a large wrought iron washer, and shown detached at fig. 19.

Screw bolts pass through the back flange, and front bindplate, the nuts turning against the face of which, brace all together as one solid nave. There is one of these bolts to each spoke, as shown in the figures.

The spokes throughout are of a parallel thickness, as shown in fig. 18, the edges being slightly rounded off.

Mr. Hancock has used this wheel with great success.

Mr. Theodore Jones's patent wrought iron suspension wheel is also worthy of description.

The rim (*a a*, fig. 22), is made of wrought iron; it is rolled in a straight bar with the rib (*b b*) on the inside to strengthen it (the same letters denote in each figure the same part). Fig. 23 is a section of the rim. The bar is cut to the length required for the intended wheel, and the ends scarfed; it is then made red-hot, and bent to a circular form, and the ends shut together; after which, conical holes (*c*), represented by dotted lines, are formed through the rim to receive the heads of the spokes: on the other end of each spoke a screw is formed. The spokes are passed through the holes in the rim and into the nave, where they are secured by a nut upon the end of each.

It will be observed, that the spokes are of such a length that their ends in the nave do not reach, or bear against the box, neither have they any shoulder against the outside of the nave; the object of which is, to prevent any support by pressure upon the rods, and the weight is therefore entirely hung or suspended by the rods, which happen to be above the nave, and from that part of the rim which happens to be uppermost. The object of suspending the whole weight by the upper, without allowing any support from the lower rods, is to save the wheel from the injury of violent shocks, which this construction effects, by affording the means of compensation, *i. e.* it allows the lower rods liberty to slip (or retire) into the nave, on whatsoever side the rim may be compressed by a heavy jolt, which it must be observed is only momentary, for the elasticity of the rim is sufficient to recover its circular form in an instant. The patentee considers that cylindrical wheels are better made on the principle of suspension than on the principle of pressure.

The durability of iron, the material of which these wheels are made, is a most important advantage in their favour, while the perishable character of wood is notorious—indeed, from a statement made at a general meeting of the master wheelwrights, by an account taken from several of their books, it was determined that the average time a set of wood wheels will last, is two years, though they agreed that in many cases they will not wear nearly so long.

Besides which, it is well known that long before the tire is worn away it becomes loose, and a source of frequent expense; and it may be taken as a general rule that every tire put upon a wood wheel is useless before a third of it is worn away. But with these wheels the tire is made in one piece with the rim (which is a substitute for the felloe in common wheels), and consequently will wear to the last without ever becoming loose; and as twice the thickness is given for wear and tear, that circumstance alone renders them twice as durable.

But frequent cases occur of wood wheels splitting and perishing long before the tire is worn out.

I have been assured that there are many instances of these iron wheels having been in work nearly four years, without costing one penny—some in wet tan yards, where the wheels look as well as the day they were made; some on carts or wagons for carrying grains, which is heavy work, and exceedingly destructive to wood wheels.

Iron wheels are not so liable to splinter and fracture as wood; this was proved in the most satisfactory manner at an experiment made upon Jones' wheels, by request of the Honourable Court of Directors of the East India Company, at the Royal Arsenal, Woolwich.

An iron wheel was therefore fired at, and the first shot cut through two rods as clean as if cut with a sharp instrument, and without the smallest fragment flying off. The next shot was aimed at the rim, which it cut through, but notwithstanding, the rim in that state was so exceedingly strong, that the wheel was used to convey the gun to a considerable distance, much to the admiration of all present. A wood wheel was then fired at, and the first shot broke one spoke, and the splinters from that broke a second: the next shot at the tire knocked the wheel to atoms, and some of the splinters were thrown to a considerable distance.

It is needless to say these wheels are being generally introduced already for carts and light vans.

The *cast*-iron nave is the weak point of this wheel; and when used for locomotive purposes, a *wrought*-iron nave should be employed. And the greatest objection to the adoption of these wheels for high velocities, is in the rattling noise which the spokes make by being loose in the nave.

Fig. 24, plate XIII, is a perspective view, and fig. 25 is a cross section, of Mr. Pennock Tigar's wrought-iron wheel, for which a patent has recently been obtained (enrolled 14th March 1834). The spokes are either made of solid iron rods, or of hollow iron. By using the tubes greater lightness is obtained, because a smaller substance of iron will suffice for a certain strain when the spoke is hollow than when it is solid.

It is a great object to have the spokes of a wheel so made and arranged that the rim shall always be kept at the same distance from the centre of the nave, *i. e.* that all the radii of the wheel shall be of equal length. This the patentee accomplishes by screwing the spoke into both the rim and the nave. The whole of this wheel is formed of *wrought-iron.* The nave, after having been forged, is turned—then bored out to receive a box, or to fit an axle. in which latter case the nave must be case-hardened. It is then tapped with screw holes, according to the number and position of the spokes. The wrought-iron rim is then prepared with screw holes, and the spokes are passed *through* the rim and screwed into the nave, at the same time that the male screw upon the outer end of the spoke is screwed into the rim. The nave and rim being thus braced together, keep their distance, and the true circle is preserved. It follows that such a wheel must carry the weight both by suspension of the axle in the spokes from the upper part of the rim, and by resting upon the spokes between the axle and under part of the rim. If, therefore, a spoke under the axle should incline to bend or to break from the weight resting on it, the spoke above the axle which suspends the weight will not elongate, and so fracture is prevented; and in the improbable case that both should incline to break, every other spoke being fixed in a similar manner, there is a combination which renders a break down extremely unlikely. This wheel, if well made, may be in practice what it is in theory, mathematically correct; and is likely to prove the best yet proposed for transporting great weight at high velocities. They are represented on the carriage, Plate I.

Mr. Stephenson's improved mode of constructing wheels for railway carriages, as described in his specification, consists in forming the spokes of iron wheels, of hollow tubes of thin wrought iron, and the ring or periphery, and nave or box of cast iron, in the manner shown by fig. 20 and 21, plate I. The tubes or spokes, after being prepared at their ends as hereinafter described, with borax to serve as a flux, are laid in their proper places within the cavities of the mould of sand or loam, as formed by the pattern of the wheel, and on fluid iron being poured into the inner cavity of the mould it will surround and attach itself to the inner ends of all the wrought iron tubular spokes at the parts where the preparation of borax has been applied, and form a nave or centre piece of cast iron. Melted iron is also to be poured into the outer cavities of the mould, which will surround and attach itself to the outer ends of the spokes at the parts prepared with borax, and form the circular rim or felloe of the wheel, which is afterwards to be surrounded with a wrought iron tire or hoop applied to it when hot, so that it may shrink or contract in cooling, in order firmly to unite and bind itself on to the wheel, after which the outer edge of the wrought iron tire must be turned to run properly on the railway. Mr. Stephenson states that wheels for locomotive carriages have been made, as described under a patent granted to himself and William Losh in 1816; the spokes of the wheels as there specified were of wrought iron of various forms (but not hollow tubes) with cast iron naves, and rims formed and united to the ends of the spokes, by running melted iron into the moulds, the cast iron surrounding and attaching itself to the ends of the wrought iron arms, but without any previous preparation of their ends with borax to serve as a flux; and also that wheels so formed have of late been hooped with wrought iron tires.

The patentee states that he confines his claims of invention under the present patent to the substitution of hollow tubes of wrought iron for spokes instead of solid bars of wrought iron heretofore used, and to the application of a preparation of borax as a flux to the ends of the hollow tubular spokes, previous to placing them in the mould, or pouring the fluid iron round them. These tubular spokes are stronger in proportion to their weight than solid bars, and will hold more securely in the cast iron nave and rim, because the cast iron is allowed to run within the ends of the tubes as well as around the outsides of the ends, and thus obtains a much greater surface of contact with the wrought iron than is obtained where solid arms are used; and also from the ends of each tube being an extended surface of thin metal, it becomes very highly heated by the fluid iron when it is poured into the mould; and in consequence of the borax applied, both inside and outside the ends, the heat of the fluid iron causes it to unite and firmly adhere to the wrought iron, whereby strong wheels will be formed for railway carriages, which are very desirable where passengers and goods are to be conveyed, with the great rapidity of motion which is practised in travelling on the Liverpool and Manchester Railway, for the violence to which the wheels are subjected in such quick travelling is so great, that no wheels hitherto tried on that railway have been found sufficiently safe and durable.

The best drag yet contrived, appears to be the pressure of a small segment upon the tire of the hind wheels.

Messrs. Heaton introduced the use of a slipper, or clog, E, for the guide to place his foot in, and thereby to regulate the exact supply of steam without requiring application of the hand.

The Earl of Dundonald's rotatory engine, having the steam ways (A and B, plate I, figs. 5 and 6) close together, and governed by a single cock, is increased or checked in velocity, or stopped, or reversed with great facility; and it is possible so to balance the action of the steam, that the carriage may be poised betwixt an advance and a retrograde movement. Mr. Joseph Maudsley has introduced a similar arrangement, which acts admirably upon a pair of vibrating engines.

Mr. Hancock's guide motion has been fully described (pp. 109, 110). The friction band and friction drum should not be omitted in any steam carriage.

It is said that a locomotive engine, a few months ago, on the Liverpool and Manchester rail-way, having been put in motion for some purpose, started off, and arrived at the end of the line, to the no small surprise of beholders. It may, therefore, be mentioned, that Mr. Gurney has contrived a security against accident in the event of the guide being thrown off his seat, This consists of a second cock or valve, which is only open when the weight of the guide presses down his seat. If he rise, the seat rises by a spring, in such manner as to close the valve, and shut off all power from the engines.

CHAPTER IX.

PROSPECTIVE ADVANTAGES.

It now remains for us to embody a few thoughts, in addition to those in Chapter I., confidently trusting that readers who have followed thus far, our details, will join with us in thinking, that what, at more prosperous times, might have been left to be slowly carried into operation by individual philanthropists, or the combined energies of a few patriotic projectors, the pressure of the times under which we write ought to force the Legislature, and that speedily, to take up as a national measure.

The POLITICAL advantages are immense. Oppressed with taxes and national debt—with an increasing pauperism and decreasing employment—we are just verging upon that crisis in our affairs, when the fortunes of all other states similarly circumstanced have irretrievably declined, and in which it becomes a matter of imperative interest and concern, that the whole of the upper classes of society should combine to direct their wealth, activity, and intelligence, to the adoption of measures, which, judiciously devised and vigorously executed, shall create a new impulse and tone under the ribs of death of the operative classes of society. Skill and enterprise can never long enable a country to maintain competition with younger rivals, when the rate of profit becomes reduced so low as to tempt the capitalist to seek a more lucrative investment in newer lands; and long before this, Great Britain would have sunk from her proud position at the head of nations, had not continuous gigantic strides been made in manufacturing and commercial knowledge—had not every day developed new inventions and fresh resources to multiply her wealth, and extend her capabilities. But all this is not sufficient: the evil has been grappled with, not exterminated; and the project which can alone consolidate our greatness, renew our body politic, and sustain us in the energies and vigour of a wholesome existence, still lies behind. Now, it unclogs the subject of a vast weight of insuperable difficulty, to consider, that the want of *method* is our bane, and not the want of *means;* that ignorance has matured the distress into which the country is unnecessarily precipitated; and that knowledge, judiciously directed, can yet dissipate it, and give it to the winds. The aggregate wealth of this great country remains unparalleled, and is amply sufficient to meet and remedy the exigencies of our case. We are not called upon to embark in a Utopian scheme to procure the *means* —that might baffle us—and afterwards to devise the *mode.* The former, amply provided, we have only to relieve from the immethod and fatuity of its present appropriation, and we have made to our hand, what will render the completion of the latter, a project of comparative facility and ease. The scheme is not a brilliant chimera irreducible to practice, but is laid up and embraced in this simple axiomatic proposition, which opposition may challenge, but we defy to overthrow:—*That the* FOOD *of the country, properly converted, is fully sufficient to extinguish pauperism; and that the fund by which that pauperism is at present upheld, encouraged, and fostered, can furnish the* MEANS *by which the conversion in question may effectually be realised.*

The poor-rates levied in England and Wales for the year ended March, 1831, amounted to the enormous sum of 8,279,217*l.* 14*s.* sterling; of which 6,798,888*l.* 18*s.*

was disbursed for the relief of the poor! Here, then, is an annual (and increasing) cancerous expenditure of upwards of eight millions of unproductive capital, eating into the vitals of the community, and creating and perpetuating the very evil which it is intended to remedy. Now such a portion of this sum as is at present applied to the purpose of supporting able-bodied paupers, is amply sufficient in itself, during the course of a few years, if it be so directed, to carry into operation this great national measure, which will give bread in the meantime to the unemployed class in question, and realise, as already shown, an effect which, in a great measure, will annihilate pauperism and redundancy altogether.

When we consider steam-carriage as an economic principle, we are relieved, by the investigations of another branch of philosophy, from the necessity of going into detail to show the *utility* of that conversion: political economists, after maturely investigating the complex causes of national poverty and distress, having come to the conclusion, that the grand source of all our evils is *redundancy* of population; or, in other words, an increase of animated life *beyond* the nourishment adequate to support it.

Perhaps we should qualify the term "beyond," because, literally speaking, population cannot exist *beyond* the means of subsistence, but *only up* to it. There is a limit to increase: "a principle in society," according to Godwin, "by which population is perpetually kept down to the level of the means of subsistence." That principle is *want of food;* the prolific parent of pauperism, unemployment, starvation, vice, disease, wretchedness, and their attendant evil train. There are, to be sure, other restrictive assistants, but this is the available one:—the grand retarder and arch enemy of our species. To live, then, *up* to the limit of food, entails upon us the host of ill just enumerated:—to live *beyond* the limit, precipitates us swiftly into famine, pestilence, and death.

But though political economists are at one as to the disease, there has been great discrepancy of opinions as to the remedy. Colonisation—emigration—equality of condition—moral restraints—community of labour and of goods—reclaiming of waste lands—artificial restrictions upon fecundity, &c., have all afforded ample themes upon which the projector and philanthropist, have erected the unsubstantial structures of their respective systems;—all beautiful as ideal theories, but all worthless in practice; because partial, temporary, or impracticable,—not applicable to the real condition, or realisable for the improvement of man.

The substitution of inanimate for animate power, if not the panacea which is to cure all the evils of our condition, is at least one that comes recommended as a matter of fact—easy of operation, and effectual in its result. If want of food, or, in other words, redundancy of population, be the bane of the country, it does not propose to meet that evil by a visionary project, tending in its operation to unhinge society—tedious in its process, and ending at length in bitter disappointment—but it meets the evil directly, substantially, and effectually, by the substitution of food. It does not raise a cry of *bread, bread,* and then conclude by giving a *serpent;* but by the application of elementary for physical power, it creates an economic principle, such as philanthropists never dreamed of; which, if not the feigned philosopher's stone, converting all it touches into gold, is a power in nature equally beneficent, since, besides its being real, it can change poverty into comparative affluence—starvation into subsistence—disease into health—misery into comfort—and vice into virtue.

And how are all these immense advantages to be effected?—By the substitution of inanimate for animate power. At present, the animate power employed in the commercial transportations of this great kingdom is estimated to amount to two millions of horses: each horse consumes as much food as is necessary for the support of eight men. Hence the conversion of its consumption to purposes of human existence would, if carried to this practical extent, amount to a quantity of food equal to support sixteen millions of people.

Where the product is so enormous—so vastly beyond our immediate necessities—it is not requisite to go into any minutiæ of detail. To calculate all the gains we will leave to the political economist; as also to bring the matter out in its fair proportions. But to establish the matter clearly within the bounds of a safe, an easy, and practical issue, we have merely to state, that a conversion of food from a physical to a moral purpose, adequate to the supply of one-fourth part of the above aggregate estimate, that is to say, to four millions, is amply sufficient to relieve us at the present moment from that pressure of pauperism which sits like an incubus upon the energies of the nation, and which will precipitate us, if not timely avoided, into speedy and irretrievable ruin.

Now the suppression of the stage-horses upon our principal thoroughfares, and of the dray-horses in the great commercial towns, may be calculated to economise a saving of food equivalent to the supply of the above number of human beings.

It is, perhaps, not superfluous to remark, that the amount of food, equal to the supply of the said four millions, is not the produce of an extended agriculture and proportionate outlay, but is just *that part* of the annual produce of the country, subtracted from the whole, which is at present required for the mere purpose of *transportation; i. e.* to feed the animals used for draught; and is consequently a dead loss, as unproductive capital. In addition to the evil arising from such a consumption of unproductive food, is also to be considered the very great loss consequent upon the heavy capital sunk in *horse* purchase.

"Dr. Colquhoun, in his estimate of the new property annually created in Great Britain and Ireland, taking each kind of grain at fifty per cent. less than the average prices in the public markets of the 12th September 1812, states the crop of hay, grass, straw, and fitches, as amounting in value to 89,200,000 *l.*

"And that the portion of this consumed by horses is as follows:—

Horses in Great Britain and Ireland, estimated at 1,800,000, at 45*s.* each, for grass	£. 4,050,000	0	0
For hay, at 6 *l.* each . . .	10,800,000	0	0
For straw, at 5*s.* each . . .	450,000	0	0
For beans and peas . . .	2,640,666	13	4
No separate item is given for corn, but taking the half of that consumed by animals generally, as consumed by horses, viz. 14,790,000 *l.* .	7,395,000	0	0
We have	£ 25,335,666	13	4

purely to support the brute labour."

In order more readily to show one effect, let the horses be considered only 1000; a smaller number may not make the argument so difficult. Let us reduce *this* number, and the farmer may then turn his oat-ground into wheat-ground; and instead of so much land being employed to furnish food for a thousand horses, the same land, when turned into tillage fit to sow wheat upon, will produce sufficient bread-corn, or food for cattle, wherewith to feed 2000 poor families.

"Again," (to use the words of a distinguished writer on canal navigation,) "if instead of 20,000 horses, we keep 30,000 fat oxen, butchers' meat will be always cheap to the operative classes, whilst the quantity of tallow will of course make candles cheap; and so many hides lower the price of leather, and of shoes, and all other articles made of leather. Or the same quantity of land may then keep 30,000 cows, the milk of which will make both butter and cheese cheaper to the poor, as well as the labouring manufacturer; all which articles are very considerable, and of material moment in the prices of our manufacturers, as they, in a great measure, work their trade to rise and fall in price, according to the cheapness of their materials and the necessaries of life. The same may be said in favour of more sheep and woollen cloths."

We have said, a horse consumes, on an average, as much as eight human beings. The country is burdened with poor (in want of food): so much so, that an evil is resorted to, to ease the burden; and the strongest and ablest of our peasantry are encouraged to emigrate. Our political strength is thus wasted. Whilst, therefore, we have a remedy really good and practicable before us unresorted to, we may in truth say that we depopulate our country for a "bestial herd."

But it would be taking but a limited view of this part of our subject, did we confine ourselves to the above observations, important though they be: there are great *financial* results to be considered likewise. The experience of the last thirty years has shown that we have hitherto legislated in vain for Ireland. A starving population cannot be cured either by education on the one hand, or by coercion on the other. Laws, however judicious in themselves, or beneficently administered, must fail to accomplish their purpose amongst a redundant impoverished people. It is bread they want: and this deficit has been the *fructifying* source hitherto of the disordered structure both of her political and moral condition. But let us, by the introduction of inanimate power, supply this want, and we do not, like Mr. Canning, create a transatlantic kingdom, but we resuscitate one at home, leagued to us by blood, by union, and neighbourhood. Let us *make them food,* and they will make themselves educated, and industrious, and happy, and prosperous. The yoke removed, which has hitherto bowed the neck of the finest race in the world, Ireland will rise up, though late in time, in the energies of a renewed people, to add a vast fund of financial support, instead of the heavy burden she has hitherto been to England. And if the last of the Union to attain her meridian of greatness and prosperity, she will likewise be the last to hand down the greatness and prosperity of the British empire to future times.

Nor will Scotland find less advantage from a change which will enable her to command a distant market for her home commodities; and which, at the same time, will bring all her imports cheaper to her doors. The produce of her mines will become more valuable, and property acquire a worth which hitherto it has not attained—the increase of finance returns will of course be proportionate.

In various departments of the revenue the saving of expenditure by the substitution of inanimate for animate power will also be immense. In the post-office alone, for instance, it will amount to upwards of half a million. Whilst, from the cheapness of food which the substitution will produce, the navy and army estimates will be most essentially reduced.

The corn-laws are another evil which the adoption of this great measure will completely extinguish, as we have shown—not indeed by their repeal, but by what is much better, the necessity for their repeal no longer existing.

Nor will corn alone become cheap and abundant, but all the necessaries of life will comparatively become equalised. No longer will local failures of crop expose remote districts to temporary visitations of famine and disease; but steam, introduced, will circulate the produce of the land in liberal profusion. Then the pilchards of the Channel will no longer be used to manure the bordering counties, when they can be eat *callar* throughout the North: nor will the exhaustless shoals of herring depart untithed from Loch Fine, because no inland consumption holds out a bonus for their capture.

It is not difficult to perceive how all these important results will enable the country to bear lightly (perhaps to liquidate) the national debt. The payment of the taxes, under a system where pauperism and redundancy will be alike unknown, will no longer be a burden.

It will be argued that an increase of food, or subsistence, will *increase* our population, and eventually precipitate us into worse calamities than what it for the present remedies. No doubt our population will increase; for increase and prosperity are terms that are relative. But what then? If we can relieve many generations from the consequence of reaching the limit, (*i. e.* of poverty, vice, misery, and disease,) are we to avoid doing so because society will grow progressively till it again meets the limit? We trow not: as sensible were it never to eat when hungry, because we shall again be hungry! Our business is to postpone the evil day, and to allow subsequent generations to economise for themselves. Is it reason, or humanity, or interest, or duty, to avoid getting rid of the fearful crisis of national misery that is setting in upon us, because we are met with the hypothetical supposition, that a similar crisis may be the lot of our descendants one hundred and fifty years hence? No: not to avoid the crisis is to perpetrate a national *felo de se*, at the expense of all the moral obligations which man owes to God, himself, his neighbour, and society.

The AGRICULTURAL advantages are equally great; if possible, more important.

In the opinion of Colonel Torrens, agriculture is prosperous in proportion as the quantity of produce brought to market exceeds the quantity expended in bringing it there. If steam-carriages be employed instead of carriages drawn by horses, it will be because that mode of conveyance is found the cheapest. Cheapening the carriage of the produce of the soil must necessarily diminish the quantity of produce expended in bringing a given quantity to market, and will therefore increase the net surplus, which net surplus constitutes the encouragement to agriculture. For example: if it require the expenditure of two hundred quarters of corn to raise four hundred, and the expense of one hundred more, on carriage, to bring the four hundred to market, then the net surplus will be one hundred. If, by the substitution of steam-carriages, you can bring the same quantity to market with an expenditure of fifty quarters, then your net surplus is increased from one hundred to one hundred and fifty quarters; and, consequently, either the farmer's profit or the landlord's rent is increased in a corresponding proportion. There are many tracts of land which cannot now be cultivated, because the quantity of produce expended in cultivation and in carriage, exceeds the quantity which that expenditure would bring to market. But if you diminish the quantity expended in bringing a given quantity to market, then you may obtain a net surplus produce from such inferior soils, and consequently allow cultivation to be extended over tracts which could not otherwise be tilled.

"On the same principle (says Colonel Torrens) lowering the expense of carriage would enable you to apply additional quantities of labour and capital to all the soils already under cultivation. But it is not necessary to go into any illustrative examples to explain this: it being a well-known principle, that every improvement which allows us to cultivate land of a quality which could not previously be cultivated, also enables us to cultivate, in a higher manner, lands already under tillage.

"The beneficial effect upon the profits of trade, by bringing agricultural produce more cheaply to market, will tend to increase profits, to encourage industry, and to enlarge the demand for labour; so that, by this gradual process, there will probably be no period during which any land can actually be thrown out of cultivation, the increasing population requiring all the food which horses would cease to consume. With respect to the demand for labour, that demand consists of the quantity of food and raw materials which can be cheaply obtained; and as, by the supposition the displacing of horses will leave at liberty more food, and more material, the demand for labour will ultimately be greatly increased, instead of being diminished.

"When we take further into consideration, that lowering the expense of carriage would enable us to extend cultivation over soils which cannot now be profitably tilled, and would have the further effect of enabling us to apply, with a profit, additional portions of labour and capital to the soils already under tillage, I think it not unfair to conclude, that were elementary power on the common roads completely to supersede draught-horses, the population, wealth, and power of Great Britain would at least be doubled.

"If there are soils of such a peculiar quality that oats are the only marketable product which they will yield, the persons employed in cultivating those lands would certainly be thrown out of that particular occupation; but the extension of tillage over other lands not of this peculiar quality would create a demand for labour which would much more than absorb the persons thrown out from the culture of oats upon that land which would grow nothing else. But I doubt of there being any land which it is profitable to cultivate, which would not raise some other agricultural produce than oats, either for man or cattle, for which the increasing population would create a demand.

"Supposing that steam-carriages should be employed in conveying passengers only, and the whole change to be effected in a sudden manner, I think that there would in the first instance be a diminished demand for agricultural produce, but the following process would take place. As the demand for agricultural produce was diminished, the price of such produce would fall, food would become cheaper, and the cheapening of food would benefit partly the labouring class and partly the capitalists, the one obtaining higher real wages, and the other higher profits; this increase in real wages and in profits, would effect a great encouragement to manufacturing industry, and would necessarily lead to an increase in the manufacturing population, and to the amount of capital employed in manufactures. The consequence would be, that after some degree of pressure upon agriculture, the increased number of human beings would create the same demand for agricultural produce which the employment of horses formerly created. So that, even upon the extreme and most improbable supposition, that steam-carriages should never be employed in conveying agricultural produce to market at a cheaper rate, still the benefit to the country would be very great, inasmuch as we should have a vastly increased industrious population, and England would become much more extensively than she is at present the great workshop of the world. In point of fact, superseding horses by mechanical power would have precisely the same effect in increasing the population and wealth of England, as would be produced were we to increase the extent of the country by adding thereto a new and fertile territory, equal in extent to all the land which now breeds and feeds all the horses employed upon common roads. Such addition to the extent of fertile territory in England, suddenly effected, would in the first instance lower the value of agricultural produce, and be injurious to the proprietors of the old portion of the territory; but no person would therefore contend, that if we could enlarge the Island of Great Britain, by additional tracts of fertile land, the public interests would be injured by such enlargement: this would be monstrously absurd. It is not less absurd to object to the increase of food available for human beings, by substituting mechanical power for horses.

"In addition to these advantages from the introduction of steam-conveyance, the increased speed and cheapness of intercourse would occasion vast public benefits, in which agricultural capitalists and labourers must greatly partake.

"The cost of bringing all things to market is comprised of the cost of production and the cost of carriage. Reducing the cost of carriage is precisely the same thing in its effects as reducing the immediate cost of production; consequently, the conveyance of light goods by steam-power must cheapen all such goods to the consumers. This will necessarily enable them to consume a greater quantity of such goods; and the consumption of the greater quantity will enlarge the demand for labour, call a larger manufacturing population into existence, and thereby re-act on agriculture by increasing the demand for food. This cheaper mode of internal carriage will not only lower the price of light and refined manufactures to the home consumer, but will lower their price also to the foreign consumer. This will increase the advantages which we at present possess in the foreign market, and tend to increase our foreign commerce. So that here again there will be an increased demand for manufactures and for a manufacturing population, and here again will be another beneficial re-action upon the soil. So that the more we contemplate the various effects produced upon the industry of the country by a cheaper mode of conveyance, the more we must be convinced that wealth and population will be increased, and that agriculture, instead of being injured, must necessarily partake in the increased prosperity of the country. In addition to what I have already stated, the saving of expense and of time in conveying passengers and goods, and the rapidity of communication, will produce effects, the amount of which it would be almost impossible to calculate."

Notwithstanding all this, we are still told that steam-carriages will never do the country any good.

That mighty agent which, at the word of the Omnipotent, removes hills, and overturns mountains, exalts valleys, and rends the earth; and which *may be* instrumental in the "wreck of matter, and the crash of worlds," when lent to man does weave a fabric delicate in texture as the gossamer's web. How few know that a pound weight of cotton can be spun into a thread 167 miles long*; that in one factory alone, steam spins, in a single day, thread, 60,000 miles in length, and yet so delicate that your breath could break its continuity.

It were a curious but a fair analogy to draw betwixt

* Having in my public lectures used this argument, it was reported in the Times and some other newspapers of the day, and I was not a little surprised to find some of them had headed it with "A Long Yarn." A celebrated pound of cotton spun at Manchester, for presentation to the Queen, was 185 miles long.

cotton productions and agricultural productions. In the former, it does every thing; in the latter, what? Had not this beneficent agent been extended to us, our cotton manufactures and many others would now be requiring protecting duties to encourage home production. The steam-engine renders such unnecessary, and we have not only abundance at home but a ready market every where abroad.

India was formerly our rival in cotton fabrics; how has the steam-engine altered the case? now although at Calicut (the place which gives calico its name) in the East Indies, labour is only one-seventh of what it is in this country, we are enabled, I may say, by steam-engine power, to card, spin, and weave Calicut *grown* cotton at Manchester—to dye it—to print it—and, after affixing the Oriental mark, to export it again to India:—not only is their cheap labour of no avail, we rival them in their own market after a carriage of 28,000 miles, and they cannot tell the difference of the article.

Now what is the case of our agricultural produce? Continental farmers can produce grain for 30*s*. which our farmers cannot produce under 60*s*. Can it not be produced for less? certainly it can. The anticipations of the future are strongly connected with the past. We see the dawn of brighter things for renovated England. Not an obscure indication, but a distinct appearance; the power of mind is advancing with an *accelerated* force, and by saving time we are even adding to that already accelerating force.

Need we stay to calculate that every ten hours saved from unnecessary delay in travelling is the daily power of one man's mind saved to the country. And that thus the mental power of the country will be increased, without in this case any proportionate demand for food.

This redemption of mind will in rapid accumulation bring its blessings to our species.

Agricultural produce costs in England twice the sum which it does on the Continent. The question then is, Can it not be produced for less? Certainly. If we remember, that 60 years ago, a pound of cotton could only be extended to a thread 1700 *yards* long, and this, by the close and diligent application of a *man* for the *whole day*; but that now, by steam-power, a pound of fine cotton can be extended into a thread of 167 *miles* long, with the attendance of a mere child.

Is it too much then to expect, that when the steam-engine is our motive power on roads, and extends its blessings to agriculture, to plough, to harrow, and to reap, that then corn restrictions will be nugatory, that thereby we shall have abundance at home, and may even export our corn? The cases are analogous, the results of machinery will be similar.

A very interesting parallelism could be drawn between the results of steam, as applied in our cotton and other manufactures, and the anticipated introduction of steam locomotion. But we must pass on to the coach-masters' interest.

The profits of coach contractors, already spun out to the utmost limits, will soon turn the scales, and the balance will be against them. There are seasons of profit to the coach contractor, for there are seasons for travelling; there are the periodical journeys of business, and the fashionable migrations of company; there are the recreating months of summer, and the merry days at Christmas: certain periods of the year pay well. Then arise other coach owners, lured by the gain of a profitable season. They have not only to contend against the changes of season, when there are few travellers, and when they are still obliged to keep up their extensive studs of horses, and men to attend them, although there be so little traffic on the road, that they even run their coaches at a sacrifice, in order to lessen that loss, which would be greater if horses and men were consuming food, attendance, and wages, without making any return at all. But, even during flat seasons, the horses must be kept, and men to attend them; the one must be paid wages, and the other must have food and farriery.—The establishment cannot be reduced, because the coming season holds out a hope of work to require all its strength.

Then there are the fluctuations in the price of horse-keep. The enormous loss of horses, by the quick speeds which now obtain; speeds which have by fractures, galled withers, dislocations, sprains, feet beaten to pieces and wind broken, ruptured blood vessels, and hearts broken in efforts to obey the whip, reduced the average life of post-coach horses to only *three years* of duration! Is not this a most condemning fact against the present system?

Over and above all, there is the physical incapacity of the horse for high speeds. The tractive power, which a horse can exert, in quick travelling, is a very trifle of what he can exert, at the speed which the Almighty has regulated as his maximum effect. Two miles and a half per hour is the speed at which a horse can do most constant work. Going at this rate, he can easily work eight hours a day, drawing a (light) load, equalling, in effective power, 100lbs.* Multiply his time into his speed, and we have twenty miles a day, and his total daily work may be expressed by 2,000lbs. What farmer ever thinks of trotting his plough?—none; he knows the practical value of the

* That is to say, 100lbs. suspended over a pulley, could be raised at the speed of two miles and half, by a horse travelling at the rate of two miles and a half per hour; and this for eight successive hours, or twenty miles *every day*. It is not the weight a horse can move on a road, but what he can move over a pulley. A porter can easily carry 130lbs., nay, a man can have himself so placed, that he can, by extending himself, raise 1,500lbs.!! but, when he attempts to move a weight over a single pulley, he cannot raise more than about one-thirtieth of that weight.

slow speed of the horse to be incomparably greater than a quicker one.

A coach owner travels four horses at ten miles an hour; and the amount of the whole time he can keep these four horses going, in succession, is seven hours and a half: so that, in *time*, they have lost half an hour's work, which the slow-going horse gave; nor can it be said, that although they lose *time*, they gain in *distance* travelled.—No, they lose distance in a much greater degree. Each of the stage horses can only do fifteen miles a day; so that, in *distance* one quarter is lost; nor can it be said, that in *work done*, they atone for time lost and distance lost.—No: the horse, at two miles and a half per hour, did daily work, expressed by 2,000 lbs., but the horse, at ten miles in the hour, only exerts a force, or actual pull on the collar, of 25 lbs.; which, at fifteen miles a day, may be expressed by the figures 375 lbs. Thus, then, comparing the slow-going horse (at two miles and a half per hour,) and the quick-going horse (at ten miles per hour,) you have lost in every way you look at it; and the work done in the former case is 2,000 lbs., whilst the work done in the latter case, is only 375 lbs., a loss of 1,625 lbs. by the quick speed!

Thus, we can see how coach-masters do not make the money they did in days of yore, when six miles per hour was the maximum speed. Thus, we can see a reason why the stage coach trade yields less profit than any other business requiring capital, carried on with spirit, in the country. At the speeds of from six to eleven miles an hour, the actual power of the horse's pull on the collar has been, at 6 miles = 81 lbs., at 7 miles = 64 lbs., at 8 miles = 49 lbs., at 9 miles = 36 lbs., at 10 miles = 25 lbs., at 11 miles = 10 lbs.

Lest any should not understand us, upon the actual tractive force, let us say a coach, when put once in motion, obtains what is called the *momentum*—a tendency to run without power; this *momentum* would carry the carriage constantly on, were it not retarded by the air, the resistance of the ground, and the friction of the wheels and bearings, together with collision and gravitation. The first is of small moment, the others have been fully treated of in Chapter V. and VI. If a wheeled carriage be pushed on a very smooth surface, it will run for a few seconds by itself; it is only stopped by the abovementioned forces. Suppose a horse, trotting by *the side* of such a carriage, as a boy does by the hoop which he trundles, it is clear that the force, to continue the momentum which the body has obtained, is very little, and the faster the carriage or the hoop runs, the less aid it will require to be extended to it to keep it up. The horse may be considered as occasionally extending that force in aid; but he must keep up with the carriage to be able to do so; and at the speed of 6, 7, 8, 9, 10, or 11 miles, he is only able to give out the force, which we have stated above, in the corresponding figures of 81 lbs., 64 lbs., 49 lbs., 36 lbs., 25 lbs., and 10 lbs. The coachman knows well, that the carriage often runs as if by itself, because the traces are slack—this is the same self-motion as is seen when the boy does not require to re-touch the hoop. The stage coachman knows, that he cannot at once start his coach (weighing, load and all, three tons,) into a speed of ten miles an hour. On the contrary, the horses lean forward, and struggle to get the coach moved from its state of rest; then they are gradually enabled to get it to move with more speed: ultimately, it only requires a very little extension of power to give it greater velocity. We may therefore consider the horse as working unnecessarily a great part of the time; that is to say, he has to run in harness only to use his power when it is wanted;

and every ostler knows that a horse cannot do as many miles a day by a fourth part, as a horse which only works at his maximum of $2\frac{1}{2}$ miles an hour.

All these reasons conspire to ruin the coach-masters, and discomfort the inn-keepers.

"The adoption of steam-coaches," says Mr. Farey, "will set the trade free from its great commercial difficulty, because they can be laid up and kept idle without considerable loss, and brought out again when wanted, without any new outlay; also fuel does not fluctuate either in price or quality, to any considerable extent, like horse corn. In short, the capital embarked in a steam-coach trade will not be so rapidly wasted as at present in horses. Owing to the great number of horses which must be first bought and then kept to do the same work as one steam-coach, the first outlay in stock will be very small in steam-coaches, compared with horses; the same of stables, ostlers, and harness. The daily expenses of fuel and attendants will be very much less than that of horse keep and attendance; the wear and tear of the coaches and all that is coachmakers' work will be only the same as at present; but the wear and tear of engines and machinery, though a very expensive item on each engine, will be nothing to compare with the present repairs, loss and decay of horses, because the number of engines is so small. Stage-coach horses require to be all renewed every three years, notwithstanding a heavy annual expense for what may be called repairs of horses; viz. harness, shoeing, and farriery. Engines, with an equally heavy annual expense of repairs to that of horses will, when perfected, be kept up thereby in such a state as to last for many years without renewal. The metal parts of machinery only wear at particular places, which are capable of being repaired or renewed, so that they become as good as new; but a horse when worn to disease at any part, feet, eyes or lungs, becomes incapable of stage-coach work for ever afterwards.

"The consumption of fuel, according to distance, would be the same, whether for a quick speed or for a slow speed; but when profit is considered, every thing is in favour of quick speed; because all goods carried slow must be carried cheap; and quick conveyance will bear the highest price of carriage, on account of the expense of going quick by horses. For instance, a ton of goods may be carried a mile by steam-power with a certain consumption of fuel, but it should take no more fuel to carry it a mile, at the rate of two and a half miles an hour, than at ten miles an hour; there is some qualification to be made in that statement according to the state of the roads. It will be true if they are hard and good; but if they are heavy, the expense of fuel will be a little more for the quick speed than for the slower speed; and it is also to be understood, that the engines must be suitably proportioned for attaining quick speed, because engines which are only adapted for slow motion do not work to so great an advantage when they are urged to work quick as when they are worked at or below the speed which the proportions of their parts are adapted to move with; nevertheless, that extra expense of going quick by steam-power will be but small, and nothing like the increased cost of travelling quick with horses; for horses have only a limited speed at which they can travel if they have no load to carry or drag after them, the whole of their muscular strength being then required to advance the weight of their own bodies; the speed with which stage-coaches now travel approaches so near to the speed with which the horses could travel without any load, that their force of draught becomes very small."

There is a material advantage in the application of the power of a steam-carriage over the application of horse-power. When a horse moves forward, the centre of gravity of his body and of his whole frame describes a continued series of curves making an indented line. This motion will be best seen, when we look from one side of a high wall at the head of a man on horseback, upon the other side of the wall. The rider's head will be more or less seen as the horse moves, even in a walk. If the horse trots, the curvilinear motion will be still more obvious. The horse moves in a series of curves, his feet being the centres. When he walks he leans forward, and as he falls forward, advances his feet to support himself. When he has to draw a heavy carriage, he is obliged to go slowly, at a walk, and the alternate rising and falling of his body when he does so, communicates to the carriage a succession of tugs. This is easily felt in a gig, either when the horse walks or trots, and it is always discernible in going up a steep hill with one horse. When the carriage has four-horses the tugs cannot be so distinctly felt, but still they are perceptible; therefore, the horse working by a succession of impulses, has the *vis inertiæ* to overcome at every step. This, the steam-carriage, driving by the wheel, has not to do; having one cylinder always in full force, the carriage has a *continuous roll onward*, and the *vis inertiæ* requires not to be overcome, except when the carriage is at first started.

A great deal of the horse's power, in drawing a carriage, is obtained by his leaning forward. When leaning forward, he puts out his feet to support himself; and this movement of the feet we cannot calculate, as it is involved in a physiological law known only to our Omnipotent Maker. But we do see that every animal moves with great ease on a level, whilst moving up an inclination is distinctly seen as distressing. It is this which makes a hilly road so oppressive to an aged person. His muscular power is easily and imperceptibly put forth on a level;

but when he comes to a hill, the power required to lift his body is very distinctly seen to oppress him. A horse has the same facility in moving on the plain, and the same difficulty in moving himself up a hill; and the *animal's* power required to move himself up a hill is to the *animal's* power required to move himself on the level in a much greater ratio than the ascent is to the level: whilst with *elemental power they are in the same proportion to each other.* So we arrive at the conclusion, that hilly roads are much less objectionable for steam-carriages than for horses.

In viewing the MORAL advantages which must result from steam-carriages, we find them of no less importance. There are but few so constitutionally indifferent to acceleration in travelling as the Hollander, who delighted in the "old, solemn, straight-forward, regular Dutch canal speed —three miles an hour for expresses, and two for jog or trot journeys." Acceleration in the speed of travelling, if unaccompanied by danger, is eagerly sought after, because the period of discomfort is lessened. But steam-carriages will not only lessen the discomfort by shortening its duration; they can be so equipped that positive comfort, nay, luxury, may be enjoyed. A steam-engine is perfectly under controul, and consequently much more safe than horses. The life of the traveller cannot be jeopardied by the breaking of a rein, horses being frightened, running off, &c. &c.; the steamer, it will be seen, the honourable Committee report to the House, (1831), "IS PERFECTLY SAFE FOR PASSENGERS."

Let us consider also how far humanity is outraged by the present system of quick travelling. The short average life of stage-coach horses (three years only!) shows how dreadfully over-wrought and *out-wrought* they are by the great speed now in practice. Driven for eight or ten miles, with an oppressive weight, they tremble in every nerve. With nostrils distended and sides moving in breathless agony, they can scarce, when unyoked, crawl to the stable. 'Tis true they are well fed; the interest of their owners secures that. They are over-well fed, in order that a supernatural energy may be exerted. The morrow comes when their galled withers are again to be wrung by the ill-cushioned collar, and the lumbering of the wheels. But we do not witness all the misery of the noble and the generous steed. When the shades of night impend, the reproaches of the feeling, or the expostulations of the timid traveller no longer protect him from the lash; and the dread of Mr. Martin's Act ceases to effect for a time its beneficent purpose; when the stiffened joints—the cracked hoofs—the greasy legs—and stumbling gait of the worn-out animal, are all put into agonised motion by belabouring him *upon the raw!* The expression is Hibernian, but the brutality is our own. A few ill-gained pounds reconcile the enormity to the owner—and the cheapness and expedition of the conveyance give it public sanction: but humanity is outraged by the same: human sympathies are seared; and the noble precept, that "the merciful man is merciful to his beast," is trampled under foot.

"The poet (says an anonymous writer) whose master-mind could probe deep into the source of events, did not err, when upon the agonies of the dying gladiator he linked the fall of the Roman Empire. Nor, though comparing great things with small, and however remote the effect from the cause, do we err, when we affirm that the sheep, which undergoes several deaths in its miserable progression to the slaughter-house,—though before its drivers it be dumb,—yet speaks *in signs* more potent than in words—*that* which recoils back in retribution upon our domestic hearth, and subtracts therefrom charities inversely proportionate in value to the sufferings which it has endured. The citizen who, surrounded with his family, walks the street in conscious security, and who gloats his eyes upon those episodes of cruelty which every where intersect his morning path, may scout the supposition—that the sufferings he has witnessed can leave an impress behind them that will deeply affect him in the dearest and most sensitive relations of his domestic circle; yet that such is the consequence who can misdoubt? The society, whose eyes have become habituated to the sight of blood and of blows, and whose ears are accustomed to groans and imprecations, has become, by the process, seared to those amiable and tender sensibilities which people home with its most precious affections. The fine edge of generous sentiment, imperceptibly, is worn off; the benevolent feelings within, are petrified, which enable us to extract from existence its fragrance and its sweets. And for the warm, active, radiant, sympathetic humanity,—which to its possessor is happiness, and kindliness to all,—are substituted the cold, unfeeling, heartless inanities, which rob life of half the felicities of its moral constitution. The man who is familiarised with agonies, and callous to the sufferings of the brute creation, carries out with him (speaking comparatively to what otherwise would be his experience) into the world, like Cain the first murderer, —a brand, but with this exception,—that it flares not upon his brow, but encrusts his heart, which makes him an out-cast and vagabond from all that is most lovely and peaceful in that nature, which, though fallen from its primeval excellence, is so fitted up for his comfort and happiness, that he will find in it a dwelling place of rest, and of affection, amid the plains of his inheritance, unless he wilfully make his breast a lair of brutal and disordered feelings!"

In this country, of all others on the globe, it may be most truly affirmed, that man earns his bread by the sweat of his brow, and that in sorrow he eats of it all the days of his existence. There is no proportion whatever between the labour done, and the remuneration that requites it. Ten hours of continuous tear and wear of muscular exertion daily, for six days in succession, is at present, from the high price of food, barely sufficient to earn as much wages as will keep soul and body together. There is a crying grievance in this system; but what is more to our point, there is a fatal evil in it also. However profitable a cheap rate of wages may appear to the employer, it is in reality accompanied with drawbacks which render it in the main infinitely disadvantageous and undesirable. It is, in fact, the parent of the poor-rates—that evil which now costs us eight millions sterling, and which, growing annually, if not checked, will piece-meal convert England into one vast poor-house. Now under a system, which we say will reduce the price of provisions one-half, *i. e.* which will enable a labourer, for three days' wages, to procure as much food as he now does for six—you in effect create employment for *double* the labouring poor in the country. And how do we arrive at such a conclusion? Why just from the simple fact, that man labours from compulsion, not willingly. Remove the dire necessity of the case—make his daily bread not the result of his daily exertion, and you subdivide labour in such a way, that you generalise its product, as well as equalise it. The ditch and the road, the spade and the pick-axe, are not so inviting that man will cling to them, even for love of the payment, except when the alternative is abject beggary and starvation.

The remark is almost a superfluous one, that a measure which will benefit the poor of our community, will benefit the rich also. If it be true that the wealth of the richer classes seeks down, diffusing comfort and prosperity among the lower classes; so is it equally true, that the distress of the poorer orders seeks up, communicating the baneful effects of embarrassment and retrenchment throughout all the ramifications of upper society. The sanity of the body-politic, like that of the body-physical, can only be maintained by the whole members' economising for each other's welfare.

Now if arguments such as these be potent to awake and direct the attention of the interested part of our readers, is it possible, do we conceive, to bring forward, to enlist the Christian philanthropist in the cause, an appeal equally splendid in conception,—as affecting in detail—or more powerful to arouse and direct our moral sympathies, than what follows, from the pen of the eloquent Professor of Moral Philosophy in the University of Edinburgh? Speaking of the operative classes of society, and the privations of their condition, he proceeds to remark: "I ask you" (says Professor Wilson) "if it be not the most melancholy parts of all the speculation that is suggested to the moral inquirer, by the condition of man, to observe what a wild and dense gloom is cast over the souls of this class, by this severe necessity of continued labour, which is, nevertheless, the great and constant source of the improvement of their condition? It is not suffering alone—that they may be inured to bear; but it is the darkness of the understanding, and it is the callousness of the heart, which comes on under the operation of the toil to which this human being, whose nature it is our province to explain, must be subjected; it is all that which is most miserable for us to behold. For if men, born with the same spirit as ourselves, are yet denied the common privileges of that spirit, they seem to bring certain faculties into the world that cannot be unfolded —certain powers of affection and desire which, we might be inclined to say, the lot of their birth will pervert and degrade. There is a humiliation laid on human nature in the doom which appears thus to rest on a great portion of the species, which, while it requires ourm ost considerate compassion for those who are so depressed, compels us to humble ourselves under a sense of our own participation in the mysterious nature from which it all flows. Therefore, in estimating the worth or the virtue of our fellow-men, whom Providence has placed in a lot which yields to them the means, and little more than the means, of supporting life in themselves, and those born of them, what moral inquirer would ever, for a moment, forget, how intimate is the necessary union between the wants of the body and the thoughts of the soul? Let us remember, that over the great proportion of our humanity the soul is in a constant struggle for its independence with the necessities of that nature in which we know it to have been enveloped. It has to support itself against irritating or maddening thoughts inspired by weariness, lassitude, and want, or the fear of want. It is chained down to the earth by the influence of one great and constant occupation—that of providing the means of its mortal existence. When it shows itself shocked or agitated, or overcome in the struggle, what ought to be the thoughts and feelings in the consideration of the wisdom of poor humanity?

"When, on the other hand, you see nature preserving itself more boldly amidst the perpetual threatenings, or unceasing assaults, of those evils from which it never can make its escape, and though pressed by its own many wants, forgetting them all in that love which ministers to the wants of others: when you see the brow wrinkled and drenched by incessant toil, the body bowed down to the dust, and the whole frame in which the immortal spirit abides, marred (but surely not dishonoured) by its slavery; and then, when, in the midst of all that depression and oppression, you see man still seeking and still finding joy, delight, and happiness, in all the finer affections and desires of his spiritual being, giving to the lips of those he loves, that scanty morsel earned by his own hungry and thirsty toil—purchasing by sweat, sickness, and fever, the useful education, and religious instruction, of the young creatures who delight the heart of him who is striving for their sakes—resting with gratitude on that day which is like a fountain in the midst of the thirsty wilderness to his exhausted and wearied frame—and preserving a high sense of his own immortality amongst all the toils and struggles that would fain chain him to the dust; when, I say, you see all this, and think of all this, you will discover how rich may be the very poorest of the poor, and you will learn to respect the moral being of man in these its triumphs over the power of his physical nature. But you do not learn from this to doubt or to deny the wisdom of the Creator. You do not learn from all these struggles, and all these defeats, and all these most glorious victories, and all these triumphs, that God sent his creatures into this state of existence to starve, or that the air, the earth, and the waters, have not wherewithal to fill the mouths that gape for food. Nor will you ever learn that want is a crime, or that poverty is a sin, or that they who would toil but cannot, or that they who would toil but have not work, are intruders at Nature's table, and must be driven to famine, starvation, and death."

Sed jam satis! we have now to close this volume: and we do so expressing an earnest and fervent wish, that the conversion of steam to economic purposes, as a scheme of interest, of duty, of humanity, and of morality, will be taken up, and that immediately, by all classes of society, with the spirit due to its vast importance. The public mind opens, we are aware, but slowly to the advantages to result from the adoption of any novel project; and when the fetters, not merely of ignorance but also of selfishness, are to be broken, it may indeed be said, hic labor, hoc opus est! We are, nevertheless, sanguine that the wonderful realities of steam, as at present exemplified, will not be impotent in relieving the public mind from scepticism as to its almost indefinite utility when directed to any specific purpose. The modification in question is one whose practicability and utility alike lie upon the surface: whose adoption can be attended by little partial evil, and be productive of great universal good. Our treatise has not been upon the science of political economy, falsely so called, involving contradiction, or devolving speculation—but explanatory of a master-movement in mechanics, which will operate throughout every department and ramification of our distressed commercial, agricultural, operative, and social community, the most important benefits. In laying down this proposition, we bring our subject to its close. And happy shall we be if we have discharged our task in such a manner as shall introduce it to the common sense of the British people. The subject-matter is one of too vast importance in itself to require an elaborate apology on our part for the shallow manner in which we have treated it. The practical man who has waded through the facts which we have detailed, will not have done so without allowing that *nous avons raison* for the conclusions that we have arrived at; nor will he shut his eyes upon the consideration, that a subject such as this, involving so many occult as well as apparent advantages, which would have appeared important even in the hands of a child, would have attained to a gigantic magnitude if brought out in the length and breadth of all its varied practical applications. We cannot but behold in perspective, the certain eventual enlarged application of that beneficent agent which now makes the stately vessel walk the water as a thing of life,—which *may* direct the gladsome plough over the mountain's side,—and which *shall* assuredly, and that at no distant date, roll the tide of human life, and the produce of human industry, through all the, once more, prosperous glens and dales of renovated England,——that we at least have done somewhat to hasten that day, by endeavouring to beget and to arouse a spirit of examination and experiment, respecting the practical adoption of a project, than which one equally splendid, and as universally advantageous in all its results, never yet engaged the attention, nor claimed the patronage, of the British people.

APPENDIX (A).

Referred to on page 13.

Report of a Meeting of Noblemen and Gentlemen, called by Mr. Alexander Gordon, and held at Fendall's Hotel, Palace Yard, April 23rd, 1833, for the purpose of forming a Society for ameliorating the distress of the Country, by means of Steam Transport and Agriculture.

Henry Handley, Esq. M.P. in the Chair.

H. Handley, Esq. having been called to the Chair, opened the business by observing, that he felt himself incapable of doing justice to the position in which the Meeting had placed him, having no mechanical or engineering knowledge, nor boasting any scientific acquaintance with the subject; he was, however, strongly impressed with its immense importance; he felt Steam to be the most mighty engine as yet confided to mortal hands, that its powers and resources had been hitherto but partially developed, and that he anticipated, ultimately, the greatest advantages to every class of society from its application to the various purposes of Transport and Agriculture.

He took occasion to observe, that he had four years ago entertained the project of its application to agriculture, and had for that purpose offered a premium for the invention of a Steam Plough; he had the assurance of many scientific men that it was perfectly practicable, and he attempted to form a Society, with a view to its encouragement, but failed; he still entertained the same opinion as to the advantages to be derived from it, and felt, that as he feared the agriculturist would receive no legislative or financial relief, the only mode by which certain inferior natural wheat lands could be retained in cultivation, would be by substituting inanimate for animate power, and thereby diminishing the cost of production; in saying this, he begged to observe that were it probable the application of such a power would tend to diminish the demand for manual labour, he for one would never become its advocate; however, on the contrary, he felt satisfied it would very materially increase it, for by displacing animal power, it would effect an enormous saving in the food of man, and a reduction in the cost of cultivation.

In allusion to the practicability of Steam Carriages on common roads, he said, that was no longer matter of experiment, it had undergone the test of experience; and the report of a Committee of the House of Commons, in 1831, had pronounced an unqualified opinion in its favour. Sir Charles Dance, who was now present, had successfully worked his carriage for four months between Gloucester and Cheltenham, and would, he hoped, favour the Meeting with his opinions and the results of his experiments; and Mr. Hancock was at that very time running a Steam Omnibus between Paddington and Moorfields. Individual enterprise and exertion could not, however, single-handed achieve the perfection which would be attainable by the co-operation of numbers, and the application of the Funds of a Company. It was with a view to form a Society for the encouragement of individual genius and exertion that the present preliminary Meeting was convened. He for one would gladly join in such an Association, and hoped some of the gentlemen present, who took an interest in it, would unite in giving an impulse to this important and interesting subject.

Sir Charles Dance having been called upon to state the result of his experience upon the subject to the Meeting, remarked, that several years ago he had been induced to consider the application of Steam to locomotive purposes as important to the military operations of the country, and had subsequently embarked capital in Mr. Gurney's experiments; that after various successful trials, his steam carriages had run, during the summer of 1831, as a public conveyance between Cheltenham and Gloucester. The distance travelled amounted to nearly 4,000 miles, without a single accident, hurt, or injury of any kind occurring; that notwithstanding this favourable success, and its gaining ground daily in public estimation, he was opposed by every one that ought to have assisted in forwarding the project, to a degree that forced him, at the end of four months, to abandon it. He was happy to find so many honourable gentlemen coming forward to promote what he considered to be a great national undertaking, and be able to say, that a few days ago he had run his steam carriage from the Bazaar, Portman Square, to Palace Yard, calling at several of the club houses on his way, and had moved through the lines of vehicles at the most crowded period in the afternoon with perfect ease and facility, and without disturbance to a single horse. That his steam carriage was now in the hands of Messrs. Maudsley, Sons and Field, preparatory to its running as a public conveyance: that this was but one—and every way inadequate to a fair trial of the project; that really no private means could bring forward the thing with justice either to itself or the projector; but, that if supported as it was entitled to be, and as now he hoped it would be, by the country, he had not a single doubt that it would succeed fully.

Sir John Sebright, Bart., M.P. stated, that having seen Sir Charles Dance's steam-carriage pass Charing Cross upon the occasion referred to, he could bear witness to the fact of the perfect management with which it was conducted through that thoroughfare—management as complete as that of any gentleman's carriage. He would also observe, with regard to Sir Charles's steam carriage having gone up Clay Hill at the rate of ten miles an hour, that from his frequent experience of the difficulty in getting over that steep ascent, in the ordinary mode of conveyance, he had no doubt a steam-carriage which did not fail there, would have nothing to fear upon any ordinary line of road in England.

Mr. Thomas Hancock being called upon to say whether his brother's invention was yet before the public, stated that a carriage, built by his brother was now running as a public conveyance betwixt the City and Paddington, daily, but he lamented that as there was only this one steam-carriage on that road, it might be stopped for a day or two now and then for repairs,—a disappointment which the public might be saved by having one or more carriages to supply its place.

Mr. Alexander Gordon stated shortly what had been done by steam-carriage inventors since the Report of the Committee of the House of Commons, in 1831. He particularly adverted to the satisfactory trials he had seen made by Sir Charles Dance and by Mr. Hancock. In the steam-carriage of the latter gentleman, he had made a trip to Brighton and back again; but he must say it was too bold an attempt for a single steam-carriage. A horse conveyance can have a remedy for any derangement about the harness or coach, but the steamer has no such facility of repair, and therefore he was rejoiced to see that so many of the powerful of the land were extending their fostering care to a project which, he trusted, they would not fail to cradle into greatness, for the benefit of every class of the community.

Colonel Torrens, M. P. during the preliminary conversation had stated, that in consequence of the opposition offered to Sir Charles Dance's Steam Carriages upon the Gloucester Line, and the petition in consequence of Mr. Gurney, he had moved for the Committee which sat upon the subject in 1831. That that Committee had given the project a patient and full investigation, and had taken the evidence of a number of eminent engineers and projectors, practically acquainted with its detail, and that the report embodied a full and explicit sense of the Committee as to its practicability, safety and utility. In again rising to move the First Resolution which met with his entire concurrence, the Honourable Member proceeded to observe, that with respect to the economic advantages that would result to society, he believed that they would be very great. That the bringing of agricultural produce more cheaply to market will tend to increase profits, to encourage industry, and enlarge the demand for labour. And that, considering how it would enable us profitably to extend cultivation, and apply with advantage additional portions of labour and capital to the soils already under tillage, he did not consider it unreasonable to conclude that, eventually, it will double the wealth, prosperity, and population of the kingdom. He begged therefore to move:—

That the application of Steam to inland transport and agricultural purposes, will, by cheapening the production and saving the consumption of the food of the country, be accompanied by advantages to all classes of the community, of the most extensive and permanent utility; and that, as such, this meeting considers it highly entitled to their support, and that of Society at large.

Seconded by J. W. Childers, Esq. M. P., and unanimously resolved.

Charles Shaw Lefevre, Esq. M.P. in rising to move the Second Resolution, said, that having been one of the Members of the Committee who sat upon the subject of Steam Carriages in 1831, he felt great pleasure in bearing testimony as to the Report having embodied the decided opinion of all the Members of the said Committee, a summary of which had very properly been introduced into the Resolution in his hand, from the various and lengthened evidence which had been adduced upon the occasion; and he felt fully satisfied that the latter clause was fully warranted by the many and successful experiments which had since been made. He therefore would move:—

That the practicability of applying Steam to general locomotive purposes was satisfactorily proved by evidence before a Committee of the House of Commons, in 1831; who reported the sam to be "practical" —"safe"—one "of the greatest improvements in the mode of internal conveyance ever introduced," and "entitled to legislative protection;" and that, since, it has been further and fully established by numerous successful experiments.

Which being seconded by Mr. Keith Douglas, was unanimously agreed to.

Mr. Leonard Coxe, in moving the Third Resolution, mentioned having lately journeyed in Mr. Squire's Steam Carriage, which, although not brought to the same perfection as Sir C. Dance's, or Mr. Hancock's (which latter he was glad to understand had just made its most successful *debut* upon the Paddington Road), in outward appearance, yet conveyed the party with great speed and satisfaction. Having long been a faithful believer in the great commercial, political and moral advantages which would arise to society at large from the general application of Steam to locomotive purposes, he had much pleasure in proposing the Resolution put into his hand, viz.—

That this meeting considers it desirable that an association be formed for bringing the measure forward in the prominent manner which its own importance, political and commercial, and the exigencies of society, require; to be called "A Society for Promoting the Application of Steam to General Transport and Agricultural Purposes:" and, that the following noblemen and gentlemen be requested to act as a Provisional Committee to carry the resolutions of this meeting into immediate effect.

W. R. Keith Douglas, Esq.
Sir Andrew Agnew, Bart., M.P.
Henry Handley, Esq., M.P.
} *Trustees.*

Most Noble the Marquess of Sligo.
Right Hon. the Earl of Kenmare.
Right Hon. the Earl of Kerry, M.P.
Right Hon. Lord Visc. Morpeth, M.P.
Right Hon. Lord Visc. Sandon, M.P.
Hon. Lord Oxmantown, M.P.
Sir John Sebright, Bart., M.P.
Sir George Cayley, Bart., M.P.
P. Maxwell Stewart, Esq., M.P.
Edward Romilly, Esq., M.P.
C. D. O. Jephson, Esq., M.P.
John Browne, Esq., M.P.
J. W. Childers, Esq., M.P.
Col. Torrens, M.P.
John Hardy, Esq., M.P.
W. B. Baring, Esq., M.P.
W. P. Brigstock, Esq., M.P.
William Hyett, Esq., M.P.
Thomas Bish, Esq., M.P.
J. Wilson Patten, Esq., M.P.
Sir James Broun, Bart.
Sir Charles Lemon, Bart., M.P.
Sir Harry Verney, Bart., M.P.
Lieut.-Gen. Sir T. Broune, K.C.H.
Col. Sir Henry Watson, K.T.S.
Major-Gen. Charles Palmer, M.P.
C. Shaw Lefevre, Esq., M.P.
Andrew Johnston, Esq., M.P.
George Traill, Esq., M.P.
J. S. Buckingham, Esq., M.P.
R. A. Slaney, Esq., M.P.
W. A. Mackinnon, Esq.
Leonard S. Coxe, Esq.
Captain Cheyne, R.N.
Robert Dobie, Esq.
Charles Mawley, Esq.
William Dundee, Esq.
R. d'A. Brown, Esq.

Alexander Gordon, Esq., Civil Engineer.

Bankers—Messrs. Coutts & Co.

Which being seconded by W. P. Brigstock, Esq., M.P., was unanimously carried.

*** Several other names have been added to this Society.

APPENDIX (B).

The following was the annual expense of horse coaches on the turnpike road betwixt Manchester and Liverpool, previous to the opening of the railway: taken from the petition to parliament of the coach-masters on that road.

				£.	s.	d.			
Duty upon 33 coaches				8455	16	8			
Assessed Taxes on servants . . .				261	0	0			
Mileage for 26 coaches to Manchester, at 13*l.* 4*s.* per day .	£4818	0	0						
Mileage for coaches to Bolton, at 1*l.* 15*s.*	638	15	0						
Mileage for coaches to Wigan, at 4*s.* 8*d.*	267	13	4						
Mileage for coaches to St. Helens . .	54	15	0						
				£5779	3	4			
							£14,496	0	0
Tolls for 33 coaches, at 18*l.* 10*s.*							8,005	13	4
							£22,501	13	4
Harness for 709 horses, at 4*l.* each .				2,836	0	0			
Iron and labour, blacksmiths', 709 horses, at 3*l.*				2,127	0	0			
87 hostlers, at 1*l.* per week				4,524	0	0			
Rent of stables and coach-offices . .				1,418	0	0			
Consumption of horses 15*l.* each, to be renewed every three years . .				3,545	0	0			
Hay and corn for 709, at 15*s.* per week				27,651	0	0			
							42,101	0	3
							£64,602	13	0

APPENDIX (C).

ALLUDED TO IN PAGE 95.

Extracts from Seventh Report of the Holyhead Road Commissioners; showing the number of lbs. required to draw a Wagon of the weight of 21 cwt. 8 lbs. at the rate of 2½ Miles per Hour.

1. PARTS on which the Experiments were tried.	2. Number of Observations.	3. Rate of Inclination.	4. Actual Draught in lbs. or proportional Number of Horses required on each station.	5. Correction for the Rate of Inclination.	6. Draught reduced, or the proportional Number of Horses that would be required if the Road were horizontal.	7. OBSERVATIONS. — All the Experiments were made in the middle of the month of March, 1830, during dry weather.
No. 1.						
Piccadilly Pavement.						
From Stratton Street to Devonshire House .	15	rise, 1 in 114	60½	20½	40	Excellent, smooth, well-laid pavement.
Devonshire House to Dover Street	14	rise, 1 — 156	48¼	15¼	33	Ditto, ditto.
Dover Street to James' Street	13	fall, 1 — 429	42¼	5¾	48	Pavement uneven, and worked into holes; the top of the stones a good deal rounded, and the joints opened.
St. James' Street to Bond Street	8	rise, 1 — 245	54	9	45	
Bond Street to Burlington Arcade	11	fall, 1 — 286	40	8¼	48¼	
Burlington Arcade to Albany Court	20	horizontal	41¾	. .	41¾	
No. 2.						
Archway Road.						
Between toll-bar and new house on the right	32	rise, 1 in 23	173	102½	70½	This road lately repaired, by putting on a cemented foundation, and covering the fifteen middle feet with broken Guernsey granite, six inches in thickness.
Between New House and Depôt No. 1.	13	rise, 1 — 23	163	102½	60½	
Between Depôt No. 1. and Archway	64	rise, 1 — 22	171	108	63	
Between Archway and lamp No. 11	31	rise, 1 — 49	115	48	67	
Between 11th and 12th lamp-posts	13	rise, 1 — 229	78	10¼	67¾	
Between 12th and 13th lamp-posts	12	horizontal	47	. .	47	
Between 13th and 15th lamp-posts	26	fall, 1 — 382	46	6¼	52¼	
Between 19th and 21st lamp-posts	35	rise, 1 — 27	151	87	64	
Between 21st and 22d lamp-posts	22	rise, 1 — 27	152	87	65	The surface not perfectly consolidated, and shaded with trees.

APPENDIX (C), *continued*

1.	2.	3.	4.	5.	6.	7.
Between 22d lamp-post and M'Pherson's . .	16	rise, 1 — 3437	59	--½	58½	On this portion Hartshill was used instead of granite.
Between Wellington Inn and Whetstone Road	20	horizontal	44	. .	44	
No. 3.						
Hockliffe and Stratford Trust.						
Near Fountain Inn, Shenley	49	horizontal	97	. .	97	12 inches of limestone; low fences.
Near Talbot Inn, north of Shenley	36	rise, 1 — 20½	232	115	117	Do., good foundation, firm and dry, not worked in.
Flat, north side of Shenley	34	fall, 1 — 119	93	19¾	112¾	12 inches limestone; plantation south side.
Ditto, near Speckland Hollow	77	horizontal	120	. .	120	11 inches pebble and limestone; plantation south side.
Crown Hill	38	rise, 1 — 45	128	52½	75½	Embankment; paved foundation, covered with 10 inches of broken limestone.
Ditto, near summit . .	26	rise, 1 — 27	136	87	49	
Between Crown Hill and the toll-bar . . .	56	rise, 1 — 66	115	35¾	79¼	12 inches limestone; no sub-pavement.
Flat between Two-mile Ash and Stony Stratford	68	rise, 1 — 3437	60	1	59	18 inches limestone; low fences, no trees.
Near same place, tried back	58	fall, 1 — 3437	57	1	58	Ditto, ditto.
No. 4.						
Stratford and Dunchurch Trust.						
Flat between 65th mile-stone and brick-house	23	rise, 1 — 20	270	118	152	6 inches limestone; low fences each side; trees and high bank on west.
Between brick-house and road to Northampton	7	rise, 1 — 21	292	112	180	5½ inches limestone; high hedges, and bank on south-west.
Over small embankment above brick-house . .	22	rise, 1 — 22¾	343	103	240	6 inches limestone; high hedges; new stone, on a week.
Between sand-pits and road to Stowe	23	rise, 1 — 39	128	60½	67½	6 inches limestone; open and low fences.
Between road to Stowe and the Angel Inn .	37	rise, 1 — 71½	95	33	62	5 inches limestone; open wide space between; low fences.
Between hollow and 66th mile-stone . . .	70	rise, 1 — 31	130	76	54	3½ inches of Hartshill, and 2 inches of limestone, on pitching.
Between 66th mile-stone and summit of hill .	80	rise, 1 — 26	145	91	54	3 inches ditto, ditto, over embankment.
Rising next hill	60	rise, 1 — 50	90	47	43	5 inches ditto, ditto, through cutting.

The preceding table was not intended for any thing further than to get practical results, the description of which could be easily understood by road-surveyors and their assistants, and even by men in the habit of driving coaches; it could not be expected that experiments made with a large unwieldy wagon, mounted with common axletrees besmeared with tar, could furnish results on which to found a refined mathematical calculation.

Extract from Mr. Telford's Report on the state of the Holyhead and Liverpool Roads.

Being authorised by the commissioners to have the machine invented by my assistant, Mr. M'Neil, (for measuring the force of traction, or the labour of horses in drawing carriages) completed, and also to have the several districts of the Holyhead road in England tried by it, Mr. M'Neil has done so, and prepared a statement, showing the results of the trials between London and Shrewsbury, a distance of 153¼ miles.

The general results of these experiments* on different sorts of roads, are as follow:—

1.—On well-made pavement, the draught is . . 33 lbs.
2.—On a broken stone surface on old flint road, 65 —
3.—On a gravel road . . . . 147 —
4.—On a broken stone road, upon a rough pavement foundation . . . . 46 —
5.—On a broken stone surface upon a bottoming of concrete, formed of Parker's cement and gravel . . . . 46 —

"The general results of experiments made with a stage coach †, on the same piece of road, on different inclinations and at different rates of velocity, are given, from which

The following statement has been calculated:

Rate of Inclination.	Rates of Travelling.	Force required.
1 in 20	6 miles per hour.	268 lbs.
1 — 26	6 —	213 —
1 — 30	6 —	165 —
1 — 40	6 —	160 —
1 — 600	6 —	111 —
1 — 20	8 —	296 —
1 — 26	8 —	219 —
1 — 30	8 —	196 —
1 — 40	8 —	166 —
1 — 600	8 —	120 —
1 — 20	10 —	318 —
1 — 26	10 —	225 —
1 — 30	10 —	200 —
1 — 40	10 —	172 —
1 — 600	10 —	128 —

* In making these experiments, a wagon weighing about 21 cwt. was used.
† Weight of coach, exclusive of seven passengers, 18 cwt.

" Having the results of these accurate trials to refer to, leaves it no longer a matter of conjecture in what manner a road should be made, to accomplish most effectually the main object, that is, diminishing to the greatest possible degree, the labour of horses in draught.

" Although the observations of scientific persons have led to nearly similar conclusions, others have been in the habit of laying down rules for road-making at variance with all the established laws of motion ; it is satisfactory to be able to produce a positive proof by actual experiment, of their opinions being wholly erroneous.

" In this view, I consider Mr. M'Neil's invention for practical purposes on a large scale, one of the most valuable that has been lately given to the public."

APPENDIX (D).

* * * * * * " The following table will show pretty nearly the increase of expense in transporting goods by stage-coaches drawn by horses up planes of different rates of ascent. Roads in general have, in some parts, steep ascents ; one in fifteen between this and Birmingham, for instance, is too much on a road of such traffic. The surfaces are not so good generally as they ought to be ; the roads should be strengthened, either with a pitched bottoming of stone, or a concrete mass, such as the Highgate Archway, or the new road near Coventry."

TABLE.

Expense of drawing One Ton over One Mile, at different Rates of Acclivity, by a Stage-Coach and Wagon.

Four-Horse Stage-Coach, average Velocity 10 miles per Hour.		Wagon, Four Horses, average Velocity 2½ miles per Hour.	
Rates of Acclivity.	Pence and Decimals.	Rates of Acclivity.	Pence and Decimals.
	d.		*d.*
1 in 10	77·24	1 in 10	52·07
1 — 15	57·78	1 — 15	28·70
1 — 20	50·47	1 — 20	22·83
1 — 30	44·15	1 — 30	18·55
1 — 40	41·25	1 — 40	16·79
1 — 50	39·56	1 — 50	15·82
1 — 60	38·46	1 — 60	15·20
1 — 70	37·68	1 — 70	14·77
1 — 80	37·09	1 — 80	14·46
1 — 90	36·64	1 — 90	14·22
1 — 100	36·28	1 — 100	14·04
1 — 150	35·19	1 — 150	13·46
1 — 200	34·64	1 — 200	13·18
1 — 300	34 09	1 — 300	12·91
1 — 500	33·65	1 — 500	12·69
1 — 1000	33·32	1 — 1000	12·53
Horizontal.	32·98	Horizontal.	12·36

APPENDIX (E).

Mr. WOOD'S TABLE,

Showing the gross load in tons, which a Locomotive Engine, capable of taking 40 tons, at 15 miles an hour, will drag at the under-mentioned velocities, in miles per hour.

Inclination of Plane.	11	12	13	14	15	16	17	18	19	20
Level.	69.08	60.	52.3	45.70	40.	35.	30.58	26.66	23.14	20.
1 in 4480	65.8	57·1	49.8	43.5	38.1	33.3	29.1	25.3	22.	19.
1 — 2240	62.8	54.5	47.5	41.5	36.3	31.8	27.8	24.2	20.9	18.1
1 — 1120	60.07	52.1	45.4	39.7	34.7	30.4	26.6	23.1	20.1	17.3
1 — 1000	56.4	49.	42.7	37.3	32.6	28.6	25.	21.7	18.9	16.3
1 — 900	55.7	48.4	42.1	36.8	32.2	28.2	24.6	21.5	18.6	16.1
1 — 800	53.2	46.9	40.8	35.7	31.2	27.3	23.8	20.8	18.	15.6
1 — 700	52.3	45.4	39.6	34.6	30.3	26.5	23.1	20.1	17.5	15.1
1 — 600	50.4	43.8	38.1	33.3	29.2	25.4	22.3	19.4	16.9	14.6
1 — 500	48.	41.6	36.3	31.7	27.8	24.3	21.2	18.5	16.	13.9
1 — 448	46.	40.	34.8	30.5	26.6	23.3	20.3	17.7	15.4	13.3
1 — 400	44.2	38.4	32.5	29.3	25.6	22.4	19.6	17.	14.8	12.8
1 — 350	42.1	36.5	31.9	27.8	24.3	21.3	18.6	16.2	14.1	12.1
1 — 300	39.7	34.4	30.05	26.2	22.9	20.1	17.5	15.3	13.3	11.4
1 — 250	36.5	31.7	27.6	24.1	21.1	18.5	16.1	14.1	12.2	10.6
1 — 200	32.5	28.3	24.6	21.5	18.8	16.5	14.4	12.5	10.9	9.46
1 — 150		24.	20.8	18.2	16.	14.	12.2	10.6	9.25	8.
1 — 100		19.7	17.2	15.	13.1	11.5	10.	8.78	7.62	6.58

"It would be extremely difficult (says Mr. Wood, in the Second Edition of his Treatise on Railroads, p. 423), to give Tables for all the different cases which may occur in practice, and we shall, therefore, give a Formula from the 'Rev. James Adamson's Sketches, of our information on Rail-roads.'"

Let E represent the weight of the engine, and a be that fractional part of its weight representing the available friction or adhesion, which produces the progressive motion of the engine wheels upon the rails; then E a will represent the engine's force of traction upon a level.

Let i be the angle of inclination;

W the weight of the carriages and load;

f the friction at the axle of the carriages, when the pressure is 1;

n the diameter of the wheel, when that of the axle is 1;

Then we have the general equation, to express the relations of those quantities.

$$E\ (a \mp \sin i) = W\ \left(\frac{f}{n} \pm \sin i.\right)$$

$$\text{Whence } W = \frac{E\ (a \mp \sin i.)}{\frac{f}{n}\ (\pm \sin i.)}$$

The upper signs give the equations for ascending slopes, and the lower for descending slopes.

If we express W as a multiple of E, then we shall be able to find the inclination at which any required proportion of the work, done on a level, may be performed.

$$\text{If } \sin i = o; \text{ then } E\,a = W\frac{f}{n}$$

And, as we have previously found $a = \frac{1}{25}$, $(= \frac{1}{15}$ of $\frac{3}{5}$ths of the weight of the engine and $\frac{1}{20}$ respectively; and $\frac{f}{n} = \frac{1}{224}$ (or 10lbs. per ton.)

When $W = 9\,E$, or $11\,E$, respectively; and hence we find, that the proper load for an engine upon a level, is 9 or 11 times its weight, as the case may be.

This formula, will afford us the means of discovering what ought to be the inclination of a Rail-road, when the traffic, in one direction, bears a known proportion to that returning in the opposite direction. If we make the ratio of these loads, expressed as multiples of the engine, to be $q : 1$, then taking the values of sin i from the equations, with the upper and lower signs separately, we have the resulting equation.

$$\text{Sin}\, i = \tfrac{1}{2} + \frac{q+1}{q-1} \times \left(a + \frac{f}{n}\right) \pm \sqrt{\tfrac{1}{4} \times \left(\frac{q+1}{q-1} \times a + \frac{f}{n}\right)^2 - \frac{af}{n}}$$

As an example, if we make $q = 3$, which is the proportion of loaded to empty carriages; $\frac{f}{n} = \frac{1}{200}$, and $a = \frac{1}{25}$. Then we have $\sin i = ,002389$, whence $W = \dfrac{E\ (a - \sin i)}{\frac{f}{n}\ (+ \sin i)} = 5.$

Therefore $q\,W = 15$. From which we find, that an engine, which on a level Rail-road takes 8 times its own weight, will, on that inclination (viz. $\frac{1}{418}$), where its performance is a maximum, with loaded carriages 3 times the weight of the empty ones, drag up 5 times its weight, and take down the inclination 15 times its weight.

If E, or the weight of the engine, be 6 tons, then the weight of the empty carriages will be 30 tons, and that of the loaded carriages, down the plane, 90 tons.

APPENDIX (F).

Report of the Select Committee of the House of Commons upon Steam-Carriages, 1831, *after taking the evidence of the following gentlemen upon the subject:—*

Mr. Goldsworthy Gurney, *Patentee.*
Walter Hancock, *Patentee.*
John Farey, *Civil Engineer.*
Richard Trevethick, *Patentee.*
Davies Gilbert, M.P., *President of the Royal Society.*
Nathaniel Ogle, *Patentee.*
Alexander Gordon, *Civil Engineer.*
Joseph Gibbs, *Patentee.*
Thomas Telford, *President of the Institution of Civil Engineers.*
William A. Summers, *Patentee.*
James Stone, *Engineer to Sir C. Dance.*
James M'Adam, *Road Surveyor.*
John M'Neil, *Civil Engineer.*
Colonel Torrens, M.P.

"The SELECT COMMITTEE appointed to inquire into, and to report upon, the proportion of tolls which ought to be imposed upon coaches and other vehicles propelled by STEAM or GAS, upon turnpike-roads; and also to inquire into, and to report upon, the rate of toll actually levied upon such coaches or other vehicles under any Acts of Parliament now in force; and who were instructed to inquire generally into the present state and future prospects of land-carriage by means of wheeled vehicles propelled by STEAM or GAS on common roads; and to report upon the probable utility which the public may derive therefrom; and who were empowered to report the Minutes of the Evidence taken before them, to the House:—have examined the matters referred to them, and agreed to the following REPORT:—

"The Committee proceeded in the first instance to inquire how far the science of propelling carriages on common roads, by means of steam or mechanical power, had been carried into practical operation; and whether the result of the experiments already made had been sufficiently favourable to justify their recommending to the House that protection should be extended to this mode of conveyance, should the tolls imposed on steam-carriages, by local Acts of Parliament, be found prohibitory or excessive.

"In the progress of their inquiry, they have extended their examination to the following points, on which the chief objections to this application of steam have been founded; viz. the insecurity of carriages so propelled, from the chance of explosion of the boiler, and the annoyance caused to travellers on public roads, by the peculiar noise of the machinery, and by the escape of smoke and waste steam, which were supposed to be inseparable accompaniments.

"It being also in charge to the Committee, 'to report upon the proportion of tolls which should be imposed upon steam-carriages,' they have examined several proprietors of those already in use, as to the effect produced on the surface of roads by the action of the propelling wheels.

"As this was too important a branch of their inquiry to rest entirely on the evidence of individuals, whose personal interest might have biassed their opinions, the Committee also examined several very scientific engineers, by whose observations on the causes of the ordinary wear of roads, they have been greatly assisted.

"The Committee were directed also to report 'on the probable utility which the public may derive from the use of steam-carriages.' On this point they have examined a member of the Committee, well known for his intelligence and research on subjects connected with the interests of society, and they feel that they cannot fulfil this part of their instructions better than by merely referring the House to the evidence of Colonel Torrens.

"These inquiries have led the Committee to believe that the substitution of inanimate for animal power, in draught on common roads, is one of the most important improvements in the means of internal communication ever introduced. Its practicability they consider to have been fully established; its general adoption will take place more or less rapidly, in proportion as the attention of scientific men shall be drawn by public encouragement to further improvement.

"Many circumstances, however, must retard the general introduction of steam as a substitute for horse-power on roads. One very formidable obstacle will arise from the prejudices which always beset a new invention, especially one which will at first appear detrimental to the interests of so many individuals. This difficulty can only be surmounted by a long course of successful, though probably unprofitable, experiment. The great expense of the engines must retard the progress of such experiments. The projectors will, for a long period, work with caution, fearing not only the expense incurred by failure, but also that too sudden an exposure of their success would attract the attention of rivals. It is difficult to exemplify to the House how small and apparently unimportant an adaptation of the parts of the machinery, or of the mode of generating or applying the steam, may be the cause of the most rapid success; yet he who by a long course of experiment shall have first reached this point, may be unable to conceal the improvement, and others will at once reap the benefit of it.

"The Committee are convinced, that the real merits of this invention are such, that it may be safely left to contend with these and similar difficulties; there are others, however, from which the Legislature can alone relieve it. Tolls, to an amount which would utterly prohibit the introduction of steam-carriages, have been imposed on some roads; on others, the trustees have adopted modes of apportioning the charge which would be found, if not absolutely prohibitory, at least to place such carriages in a very unfair position as compared with ordinary coaches.

"Two causes may be assigned for the imposition of such excessive tolls upon steam-carriages. The first, a determination on the part of the trustees, to obstruct, as much as possible, the use of steam, as a propelling power; the second, and probably the more frequent, has been a misapprehension of their weight and effect on roads. Either cause appears to the Committee a sufficient justification for their recommending to the House, that legislative protection should be extended to steam-carriages with the least possible delay.

"It appears from the evidence, that the first extensive trial of steam as an agent in draught on common roads, was that by Mr. Gurney, in 1829, who travelled from London to Bath and back, in his steam-carriage. He states, that although a part of the machinery which brings both the propelling-wheels into action, when the full power of the engine is required, was broken at the onset, yet that on his return he performed the last eighty-four miles, from Melksham to Cranford Bridge, in ten hours, including stoppages. Mr. Gurney has given to the Committee very full details of the form and power of his engine, which will be found in the evidence.

"The Committee have also examined Messrs. Summers and Ogle, Mr. Hancock, and Mr. Stone, whose steam-carriages have been in daily use for some months past on common roads. It is very satisfactory to find that although the boilers of the several engines described vary most materially in form, yet that each has been found fully to answer the expectation of its inventor. So well, in fact, have their experiments succeeded, that in each case where the proprietors have ceased to use them, it has only been for the purpose of constructing more perfect carriages, in order to engage more extensively in the business.

"When we consider that these trials have been made under the most unfavourable circumstances,—at great expense,—in total uncertainty,—without any of those guides which experience has given to other branches of engineering;—that those engaged in making them are persons looking solely to their own interest, and not theorists, attempting the perfection of ingenious models;—when we find them convinced, after long experience, that they are introducing such a mode of conveyance as shall tempt the public, by its superior advantages, from the use of the admirable lines of coaches which have been generally established;—it surely cannot be contended, that the introduction of steam-carriages on common roads is, as yet, an uncertain experiment, unworthy of legislative attention.

"Besides the carriages already described, Mr. Gurney has been informed, that from 'twenty to forty others are being built by different persons, all of which have been occasioned by his decided journey in 1829.'

"The Committee have great pleasure in drawing the attention of the House to the evidence of Mr. Farey. His opinions are the more valuable, from his uniting, in so great a degree, scientific knowledge to a practical acquaintance with the subject under consideration. He states, that he has, 'no doubt whatever but that a steady perseverance in such trials will lead to the general adoption of steam-carriages:' and again, 'that what has been done proves to his satisfaction the practicability of impelling stage-coaches (by steam) on good common roads, in tolerably level parts of the country, without horses, at a speed of eight or ten miles per hour.'

"Much, of course, must remain to be done in improving their efficiency; yet Mr. Gurney states, that he has kept up steadily the rate of twelve miles per hour; that ' the extreme rate at which he has run is between twenty and thirty miles per hour.'

" Mr. Hancock ' reckons, that with his carriage he could keep up a speed of ten miles per hour, without injury to the machine.'

" Mr. James Stone states, that ' thirty-six persons have been carried on one steam-carriage.'

" ' That the engine drew five times its own weight nearly, at the rate of from five to six miles per hour, partly up an inclination.'

" The several witnesses have estimated the probable saving of expense to the public, from the substitution of steam-power for that of horses, at from one-half to two-thirds. Mr. Farey gives as his opinion, ' That steam-coaches will very soon, after their first establishment, be run for one-third of the cost of the present stage-coaches.'

" Perhaps one of the principal advantages resulting from the use of steam will be, that it may be employed as cheaply at a quick as at a slow rate; ' this is one of the advantages over horse labour, which becomes more and more expensive, as the speed is increased. There is every reason to expect, that in the end, the rate of travelling by steam will be much quicker than the utmost speed of travelling by horses; in short, the safety to travellers will become the limit to speed.' In horse draught the opposite result takes place; ' in all cases horses lose power of draught in a much greater proportion than they gain speed, and hence the work they do becomes more expensive as they go quicker.' On this, and other points referred to in the report, the Committee have great pleasure in drawing the attention of the House to the valuable evidence of Mr. Davies Gilbert.

" Without increase of cost, then, we shall obtain a power which will insure a rapidity of internal communication far beyond the utmost speed of horses in draught; and although the performance of these carriages may not have hitherto attained this point, when once it has been established, that at equal speed we can use steam more cheaply in draught than horses, we may fairly anticipate that every day's increased experience in the management of the engines, will induce greater skill, greater confidence, and greater speed.

" The cheapness of the conveyance will probably be for some time a secondary consideration. If at present it can be used as cheaply as horse-power, the competition with the former modes of conveyanee will first take place as to speed. When once the superiority of steam-carriages shall have been fully established, competition will induce economy in the cost of working them. The evidence, however, of Mr. M'Neil, showing the greater efficiency with diminished expenditure of fuel by locomotive-engines on rail-ways, convinces the Committee, that experience will soon teach a better construction of the engines, and a less costly mode of generating the requisite supply of steam.

" Nor are the advantages of steam-power confined to the greater velocity attained, or to its greater cheapness than horse draught. In the latter, danger is increased, in as large a proportion as expense, by greater speed. In steam power, on the contrary, ' there is no danger of being run away with, and that of being overturned is greatly diminished. It is difficult to control four such horses as can draw a heavy carriage ten miles per hour, in case they are frightened, or choose to run away; and for quick travelling they must be kept in that state of courage, that they are always inclined for running away, particularly down hills and at sharp turns of the road. In steam, however, there is little corresponding danger, being perfectly controllable, and capable of exerting its power in reverse in going down hills.' Every witness examined has given the fullest and most satisfactory evidence of the perfect control which the conductor has over the movement of the carriage. With the slightest exertion it can be stopped or turned, under circumstances where horses would be totally unmanageable.

"The Committee have throughout their examinations been most anxious to ascertain whether the apprehension, very commonly entertained, that an extensive use of these carriages on roads would be the cause of frequent accidents and continued annoyance to the public, were well founded.

"The danger arising from the use of steam-carriages was stated to be two-fold; that to which passengers are exposed from explosion of the boiler, and the breaking of the machinery, and the effect produced on horses, by the noise and appearance of the engine."

"Steam has been applied as a power in draught in two ways; in the one, both passengers and engine are placed on the same carriage; in the other, the engine-carriage is merely used to draw the carriage in which the load is conveyed. In either case, the probability of danger from explosion has been rendered infinitely small, from the judicious construction of boiler which has been adopted.

"These boilers expose a very considerable surface to the fire, and steam is generated with the greatest rapidity. From their peculiar form, the requisite supply of steam depends on its continued and rapid formation; no large and dangerous quantity can at any time be collected. Should the safety-valve be stopped, and the supply of steam be kept up in greater abundance than the engines require, explosion may take place, but the danger would be comparatively trifling, from the small quantity of steam which could act on any one portion of the boilers. In each of the carriages described to the Committee, the boilers have been proved to a considerably greater pressure than they can ever have to sustain.

"Mr. Farey considers that 'the danger of explosion is less than the danger attendant on the use of horses in draught; that the danger in these boilers is less than in those employed on the railway, although even there the instances of explosion have been very rare.' The danger arising to passengers from the breaking of the machinery needs scarcely to be taken into consideration; it is a mere question of delay, and can scarcely exceed in frequency the casualties which may occur with horses.

"It has been frequently urged against these carriages, that, wherever they shall be introduced, they must effectually prevent all other travelling on the road, as no horse will bear quietly the noise and smoke of the engine.

"The Committee believe that these statements are unfounded. Whatever noise may be complained of, arises from the present defective construction of the machinery, and will be corrected as the makers of such carriages gain greater experience. Admitting even that the present engines do work with some noise, the effect on horses has been greatly exaggerated. All the witnesses accustomed to travel in these carriages, even on the crowded roads adjacent to the Metropolis, have stated, that horses are very seldom frightened in passing. Mr. Farey and Mr. M'Neil have given even more favourable evidence, in respect to the little annoyance they create.

" No smoke need arise from such engines. Coke is usually burned in locomotive engines on railways to obviate this annoyance ; and those steam-carriages which have been hitherto established also burn it. Their liability to be indicted as nuisances, will sufficiently check their using any offensive fuel.

" There is no reason to fear that waste steam will cause much annoyance. In Mr. Hancock's engine, it passes into the fire; and in other locomotive engines it is used in aid of the power, by creating a quicker draught, and more rapid combustion of the fuel. In Mr. Trevethick's engine it will be returned into the boiler.

" The Committee, not having received evidence that gas has been practically employed in propelling carriages on common roads, have not considered it expedient to inquire as to the progress made by several very scientific persons, who are engaged in making experiments on gases, with a view of procuring a still cheaper and more efficient power than steam.

" The Committee having satisfied themselves that steam has been successfully adopted as a substitute for horse-power on roads, proceeded to examine whether tolls have been imposed on carriages thus propelled, so excessive as to require legislative interference ; and also to consider the rate of tolls by which steam-carriages should be brought to contribute, in fair proportion with other carriages, to the maintenance of the roads on which they may be used.

" They have annexed a list of those local Acts in which tolls have been placed on steam, or mechanically-propelled carriages.

" Mr. Gurney has given the following specimens of the oppressive rates of tolls adopted in several of these Acts. On the Liverpool and Prescot road, Mr. Gurney's carriage would be charged 2*l*. 8*s*., while a loaded stage-coach would pay only 4s. On the Bathgate road, the same carriage would be charged 1*l*. 7*s*. 1*d*., while a coach drawn by four horses would pay 5*s*. On the Ashburnham and Totness road, Mr. Gurney would have to pay 2*l*., while a coach drawn by four horses would be charged only 3*s*. On the Teignmouth and Dawlish roads, the proportion is 12*s*. to 2*s*.

" Such exorbitant tolls on steam-carriages can only be justified on the following grounds:—

" First, because the number of passengers conveyed on, or by, a steam-carriage, will be so great as to diminish (at least to the extent of the difference of the rate of toll) the total number of carriages used on the road; or, secondly, because steam-carriages induce additional expense in the repairs of the road.

" The Committee see no reason to suppose that, for the present, the substitution of steam-carriages, conveying a greater number of persons than common coaches, will take place to any material extent; and as to the second cause of increased charge, the trustees, in framing their tolls, have probably not minutely calculated the amount of injury to roads likely to arise from them.

"The Committee are of opinion, that the only ground on which a fair claim to toll can be made, on any public road, is to raise a fund, which, with the strictest economy, shall be just sufficient, first, to repay the expense of its original formation; secondly, to maintain it in good and sufficient repair.

"Although the Committee anticipate that the time is not far distant when, in framing a scheme of toll for steam-carriages, their general adoption, and the great number of passengers which will be conveyed on a small number of vehicles, will render it necessary, not only to consider the amount of injury actually done to the road, but also the amount of debt which may have been incurred for its formation or maintenance; yet at present they feel justified, by the limited number of such carriages, and by the great difficulties they will have to encounter, in recommending to the House, that, in adopting a system of toll, the proportion of 'wear and tear' of roads by steam, as compared with other carriages, should alone be taken into consideration.

"Unless an experiment were instituted on two roads, the one reserved solely for the use of steam-coaches, the other for carriages drawn by horses, for the purpose of ascertaining accurately the relative wear of each, it would be quite impossible to fix, with certainty, the proportion of tolls to which, on the same road, each class of vehicles should be liable. To approximate, however, as nearly as possible to the standard of relative wear, the Committee have compared the weights of steam-carriages with those of loaded vans and stage-coaches. They have tried to ascertain the causes of the wear of roads; also the proportion of injury done by the feet of horses, and the wheels of coaches; how far that injury is increased by increased velocity; and also in what degree the wear of roads by loaded carriages may be decreased by any particular form of wheel.

"The Committee would direct the attention of the House especially to the evidence of Mr. M'Neil, whose observations on this branch of the subject, being founded on a long course of very accurate experiments, are peculiarly interesting and useful. He estimates that the feet of horses, drawing a fast-coach, are more injurious to the road than the wheels, in the proportion of three to one, nearly; that this proportion will increase with the velocity; that by increasing the breadth of the tires of the wheels, the injury done to roads by great weights may be counteracted. He considers, that on a good road, one ton may be safely carried on each inch of width of tire of the wheels.

"Mr. M'Adam and Mr. Telford have given corresponding evidence as to the greater wear caused by horses' feet than by wheels of carriages.

"Each of the above witnesses agrees, that, adding the weight of the horses to that of the coach, and comparing the injury done to a road by a steam-carriage of a weight equal to that of the coach and horses (the wheels being of a proper width of tire), the deterioration of the road will be much less by the steam-carriage than by the coach and horses.

"As to the injury to roads, which is anticipated from the 'slipping' of the wheels, it may safely be left to the proprietors to correct; the action of the wheel slipping, involves a waste of power, and an useless expenditure of fuel, which, for their own sakes, they will avoid.

" Apprehension has also been entertained, that although the peculiar action of the wheels may not be injurious, yet that, from the great power which may be applied, if the steam were worked at very high pressure, or if the size of the engine were increased, greater weight might be carried than the strength of the road could bear.

" Undoubtedly, in proportion to the advance of the science, will be the increase of weight drawn by an engine with a given expenditure of fuel; but there are many practical difficulties to be surmounted, before the weight so drawn can reach the point when it would be destructive of roads. There are no theoretical reasons against the extension of the size of the engines. The difficulties, according to Mr. Gurney, are of a practical nature, and only in the 'difficulty of management of a large engine.' In proportion as we augment the power of the engines, we must increase their strength, and consequently their weight; the greater weight will be a material diminution of their efficiency. To a certain extent, the power may be increased in a greater ratio than the weight: but, with our limited knowledge of the application of steam, and with the present formation of the public roads, the point will be very soon attained, when the advantage of increased power will be counterbalanced by the difficulties attendant on the increased weight of the engines.

" The weight of the steam-carriages at present in use varies from 53 to 80 cwt.; but it must be recollected that they are mere models; they were made with attention to strength only, to bear the uncertain strain to which they would be exposed in the course of experiments, and a very considerable diminution of weight may be anticipated.

" The weight drawn, at the rate of ten miles per hour, by Mr. Gurney's engine, has not, on any extent of road, exceeded the weight of the drawing-carriage; nor is it likely, with the difficulties to be encountered on the present lines of road, from their quality and the numerous ascents, that the weight drawn will be in excess of the strength of the roads. The immense quantity of spare power required to surmount the different degrees of resistance likely to occur, would render the engine too unmanageable. This will appear evident from the force of traction required to draw a wagon over the Holyhead and Shrewsbury road, which varied from 40 to upwards of 300 lbs.

" In considering the effect on roads, we must not overlook one peculiarity, in which they have a great advantage over other carriages. In coaches drawn by horses, the power being without the machine to be moved, it becomes an object of the greatest importance to give as much effect as possible to the power, by diminishing the resistance arising from the friction of the wheels upon the surface of the road. For this purpose, the proprietors of coaches and wagons have adopted every possible contrivance, so as to reduce the tires of their wheels, that a very small portion of them may press on the road; in some coaches they are made circular in their cross section, so that the entire weight of the carriage presses on a mere point; should the materials be soft, such wheels cut their way into the road like a sharp instrument. The owners of wagons too have adopted a similar plan. Mr. M'Neil states, that the actual bearing part of the tire of apparently broad-wheel wagons, is reduced to three inches, by the contrivance of one band of the tire projecting beyond the others.

"With steam, on the contrary, a certain amount of adhesion to the roads is required to give effect to the action of the machinery, or the wheels would slip round, and make no progress. It appears of little importance, therefore, so far as relates to the engine, whether the requisite amount of friction be spread over a broad surface of tire, or be concentrated to a small point; but as the wheels, by being too narrow, would have a tendency to bury themselves in every soft or newly-made road, and thus raise a perpetual resistance to their own progress, it actually becomes an advantage to adopt that form which is least injurious to the road. The proprietors who have been examined on this point, seem to be quite indifferent as to the breadth of tire they may be required to use.

"These considerations have convinced the Committee, that the tolls enforced on steam-carriages have, in general, far exceeded the rate which their injuriousness to roads, in comparison with other carriages, would warrant; they have found, however, considerable difficulty in framing a scale of tolls applicable to all roads, in lieu of those authorized by several local Acts.

"With this view, they have carefully examined the various modes of imposing toll, either suggested by the witnesses, or already adopted.

"They are as follow:—

"1. To place a toll proportioned to the weight of the carriage and load;

"2. On the number of passengers;

"3. On the horse-power of the engine;

"4. On the number of wheels;

"5. An unvarying toll.

"Each of these plans seems liable to serious objections, which the Committee beg to submit to the House.

"No plan of toll has been more frequently recommended than that of a charge in proportion to the weight of the engine and load. As this is the most plausible, and (if it could be levied without other disadvantages) would probably be the fairest standard, the Committee have considered it right to state, at some length, their reasons for not recommending its adoption.

"If weight be taken as the standard, the toll must be a fixed charge, either upon the weight of the engine and carriage, without reference to the load; or, upon an estimated average of the load carried; or, a fluctuating charge, according to the weight at the several periods of a journey.

"The first would be at least free from the uncertainty of the other two, and therefore would be preferable; but what scale of charge per cwt. could the Committee recommend as applicable to all roads? Their toll should vary according to every different rate of charge on carriages; besides, it would appear to the trustees very unjust to exclude the consideration of that which would be deemed the most material cause of the wear of their roads; viz. the load.

"A fluctuating charge on weight would be most injurious to a carriage, which will mainly depend for success on its speed; constant altercations would take place between the toll-collectors and proprietors; a minute calculation would be required at every turnpike-gate; in fact, unless an accountant were placed at each, the Committee cannot conceive how the proportions could be satisfactorily arranged; nor would there be any desire, on the part of the toll-collector, to shorten the delay occasioned by these interruptions.

"Mr. Gurney has delivered in a scale of tolls, graduated according to weight and width of tire of the wheel. As this has been drawn up by a person interested in the success of steam-carriages, it might have been expected to be more favourable to them. The Committee, however, have not adopted it, because of the difficulties and interruptions, which a fluctuating rate of toll would induce; besides, this scale purports to be intended for a road, where 3*d.* is charged for a horse drawing, and 1*d.* for a horse not drawing; the scale would be inapplicable, therefore, when the charge was 2*d.* and 1*d.*, 3*d.* and 1½*d.*, 4*d.* and 1*d.*, 4*d.* and 1¼*d.*, 8*d.* and so on. Again, what standard of weight, in relation to horse coaches, could be adopted? The average weight of loaded coaches differs very much on different roads. It has been suggested, that a loaded coach, including the weight of four horses, would weigh on an average four tons; and that if 6*d.* per horse were chargeable to the coach, 6*d.* per ton should be placed on a steam carriage; this would be unjust, as vans, which frequently weigh upwards of six tons, would only pay 2*s.*, and a steam-carriage would pay 3*s.* Even if the injury done to the road by each were equal, this would be an unfair toll; but it will appear more evidently unjust if the greater proportionate injury done by the feet of horses drawing, than by the propelling wheels, be taken into consideration.

"The object of every steam-coach proprietor will be to attain the greatest possible lightness of machinery and engine; because thereby he renders his power more efficient for the draught of the remunerating load. To place the toll on the weight of the engine, would tend to induce him to decrease the strength of his boiler and machinery to an extent which might be dangerous to the passengers, and very detrimental to the success of steam-travelling, as the public will easily be led to believe, that accidents really occurring from injudicious legislation, were inseparable from the adoption of this power as an agent in propelling carriages.

"The only fair plea for charging tolls on such carriages, in proportion to their weight, is to prevent a load being propelled or carried which would permanently injure the road; within this limit it would be as injudicious to interfere with their progressive efficiency (which can only result from improvements of the machinery and the system of generating and applying steam), as it would be to tax carriages drawn by large and well-bred horses, more heavily than such as were drawn by horses in worse condition and of smaller size and power.

"The roads at present have to sustain wagons, weighing at times, with their horses, nearly ten tons; it is in evidence, that the breadth of wheels required by various Acts of Parliament, is so easily evaded, that it affords no protection to the road; there appears to the Committee no fair reason to suppose, that steam-carriages, approaching even to this weight, will be used on any turnpike-road, at least for a very considerable period, during which the increase of weight will be gradual, and will give ample warning to the Legislature when it should interfere.

"To charge a toll according to the number of passengers conveyed, is scarcely less objectionable. If a fluctuating toll be intended, it would be as inadmissible as to propose a similar mode of charging for fast coaches, and would be open to all the cavil and interruptions to which a fluctuating toll on weight would be liable. If the toll were fixed according to the number of passengers the carriage were capable of conveying, it would imply the necessity of a licence, limiting the number of passengers, and cramping the progress of improvement of a machine, the capabilities of which can only be ascertained slowly and by continued experiment.

"It must be also recollected, that these carriages will probably have to travel for a long period without passengers, until by their punctuality and safety they shall have induced the public to venture in them. Nor is this probability weakened by the immense number of passengers who commenced using the locomotive carriages on the Manchester and Liverpool rail-way, immediately after their introduction: these engines were established among a population accustomed to machinery and steam, and therefore not entertaining the same apprehensions of its danger which will require to be surmounted elsewhere.

"The trustees of the Liverpool and Prescot road have already obtained the sanction of the Legislature to charge the monstrous toll of 1*s.* 6*d.* per 'horse power,' as if it were a national object to prevent the possibility of such engines being used. Besides, they have supplied no standard of their own conception of horse-power. Engineers have differed very much in their estimates of this power; there is not, therefore, much probability that the opposite interests of a steam-coach proprietor and toll-collector would lead to any agreement as to the meaning of the term. But suppose the Legislature were to settle this point, and to arrange that a certain length of stroke and diameter of cylinder should represent a certain power, we still fail to ascertain that which alone it is essential to know; viz. the actual efficiency of the engine. Can we regulate the density of steam at which an engine of a given size should be worked? To be effectual, it would be also necessary to ascertain the quantity of water consumed, and even this check would be inadequate with an engine on Mr. Trevethick's principle. If the toll be left as at present on 'horse power,' it would be the obvious interest of the proprietor to work with the smallest nominal power, but to increase as much as possible the force of his steam, thereby increasing the probability of explosion.

"Some trustees have placed the toll upon the number of wheels. The Committee would object to this mode of charge, if only, because it interferes between the rival modes of steam travelling, and gives a bounty in favour of that, in which the engine is placed on the same carriage with the passengers. The opposite plan of separating the engine from the carriage is that which probably the public will prefer, until the safety of the mode of conveyance shall have been fully ascertained.

"There is still a more serious objection to this mode of charge, it tends to discourage the use of separate carriages; although it must be evident, that if a certain weight be carried, it will be much less injurious to the road when divided over eight wheels, than when carried on four only. On this point the Committee must again refer to Mr. M'Neil's evidence. They cannot, therefore, recommend the House to adopt a scale of toll which shall increase in inverse proportion to the injury done to the road. It will be seen in Mr. M'Adam's evidence, that the toll on steam-coaches, imposed by the Metropolitan Roads Act, is liable to this objection.

"Some of the local Acts have placed an unvarying toll on steam-carriages. This, if moderate, would be unobjectionable; but the Committee could not propose any sum which would adapt itself to the necessary varieties of expense in keeping up different roads, by which the tolls on common carriages have been regulated. A fixed toll has, too, this disadvantage, that light experimental carriages, or such as are built solely for speed, would be liable to the same toll as steam-carriages heavily laden.

"The Committee feel that, however strong their conviction may be of the comparatively small injury which properly constructed steam-carriages will do to the roads, yet this conviction is founded more on theory, and perhaps what may be considered as interested evidence, than practical experience; they would therefore recommend, that the House should not make, at present, any permanent regulations in favour of steam. The experience which will be gained in a very few years, will enable the Legislature to form a more correct judgment of the effect of steam-carriages on roads, than can be now made. They therefore recommend that the *tolls* imposed on steam-carriages by local Acts, where they shall be unfavourable to steam, shall be suspended during *three years;* and that, in lieu thereof, the trustees shall be permitted to charge toll according to the rate to which the Committee have agreed.

"The House will have perceived, in the former part of this report, that there are two modes of applying steam in lieu of horses in draught: one, where the engine and passengers are on the same carriage; the other where the engine is placed on separate wheels, and is merely used to propel or draw the carriage. Although the difference of weight may be in favour of the former mode, yet, as on the latter it is divided over eight wheels, instead of four, its small excess cannot justify a larger toll being imposed, as it will be found much less injurious to the roads. The Committee, therefore, recommend, that in charging toll, the engine carriage and carriage drawn, shall be considered but as one.

"As it is the opinion of all the engineers examined, that the use of narrow wheels has been the great cause of the wear of roads, and that cylindrical wheels, of a certain width of tire, are not only the least injurious, but that in some states of the road, they may be even beneficial, the Committee recommend, that the wheels of the engine carriage should be required to be cylindrical, and of not less than 3½ inches width of tire. No proprietor of steam-carriages has expressed the slightest fear of any inconvenience or loss from the use of such wheels. Beyond this, the Committee would not recommend interference with the breadth of tire, or form of wheels; it should be left to the proprietors freely to select the breadth of tire they shall find most convenient, in proportion to the weight carried.

"The Committee have divided steam-carriages (intended for passengers) into two classes, to be subject to different rates of toll. The first, where the carriage is not plying for hire, or where, if plying for hire, it shall not be calculated for, or carry at any time, more than six passengers; the original cost of such machines, and the expense of working them, will sufficiently protect the roads from any great number of merely experimental carriages; and for the same reason they will not be of a weight or size likely to be injurious. A steam-carriage only calculated to convey six passengers will be solely used where great speed is required, and will be so light as to cause very little wear of the road, probably much less than many carriages drawn by the number of horses which the Committee recommend as the standard of charge for this class. The toll, therefore, proposed to be placed on this class of steam-carriages is that, which (on the several roads, where they may be used) is charged on a carriage drawn by two horses.

"In the second class they have placed all other steam-carriages, except those travelling at slow rates, for goods only; carriages of this class should pay the same toll as may be charged on a coach drawn by four horses. This may at first appear unjust from the supposed power of steam to draw almost unlimited weight. The Committee have already enumerated the difficulties hitherto encountered in attempting to propel very heavy loads on turnpike roads. They are such as to discourage the expectation, that, within any short period of time, the system will have been so perfected as to give rise to inconvenience from this source; should any hereafter be found, it will then be sufficient to remedy the defect. Until a due proportion of the parts of the machinery shall have been ascertained, the makers of these carriages will vary but cautiously from the models at present in use; their object will be, for some time, the perfecting of them, rather than the uncertain experiment of increasing their size.

"The Committee do not anticipate, that, for a considerable period, steam will be used as a propelling power on common roads for heavy wagons. It appears to have been the general opinion of the witnesses, that in proportion as the velocity of travelling by steam on common roads is diminished, the advantages of steam over horse-power are lost. The efficiency of horses in draught is rapidly diminished as their speed is increased; while, on the contrary, the weight, which could be carried or propelled, at any great velocity, by steam, could not be more cheaply conveyed, were the speed decreased to that of the slowest wagon.

"As speed, therefore, is the cause of greatly increased expense where horses are used, while with steam it is comparatively unimportant, it is probable that the latter will be chiefly resorted to when rapidity of conveyance is required. Mr. Gurney considers, that under four miles per hour, horses can be used in draught more economically than steam. Should it, however, be deemed profitable to convey heavy goods by steam-carriages, the Committee recommend that there should be as little interference as possible with the number of carts employed;

as the effect on the surface of roads would be infinitely more injurious if heavy loads were placed on a single cart, than if the same weight were divided over several. The Committee recommend, that where carriages, containing heavy goods alone, are propelled by steam, the weight of the load should be charged, without reference to the number of carts on which it may be carried.

"As a horse is able to draw from 20 to 40 cwt. on common roads, they propose that each 20 cwt. of load conveyed in, or drawn by, a steam-carriage, should be chargeable at the same rate of toll as one horse drawing a cart.

"A charge on weight is not so objectionable where goods are conveyed at a slow rate, as when speed is alone required.

"In conclusion, the Committee submit the following summary of the evidence, given by the several witnesses, as to the progress made in the application of steam to the purposes of draught on common roads.

"Sufficient evidence has been adduced to convince your Committee,—

"1.—That carriages can be propelled by steam on common roads at an average rate of ten miles per hour.

"2.—That at this rate they have conveyed upwards of fourteen passengers.

"3.—That their weight, including engine, fuel, water, and attendants, may be under three tons.

"4.—That they can ascend and descend hills of considerable inclination with facility and safety.

"5.—That they are perfectly safe for passengers.

"6.—That they are not (or need not be, if properly constructed) nuisances to the public.

"7.—That they will become a speedier and cheaper mode of conveyance than carriages drawn by horses.

"8.—That, as they admit of greater breadth of tire than other carriages, and as the roads are not acted on so injuriously as by the feet of horses in common draught, such carriages will cause less wear of roads than coaches drawn by horses.

"9.—That rates of toll have been imposed on steam-carriages, which would prohibit their being used on several lines of road, were such charges permitted to remain unaltered."

APPENDIX (G).

Alluded to page 201.

Extracts from the Prospectus of the London, Holyhead, and Liverpool Steam Coach and Road Company. Capital £350,000—in Shares of £20. each—Deposit £2. per Share.

PROVISIONAL COMMITTEE.

The Right Hon. Sir Henry Parnell, Bart., M.P.
William Ralph Cartwright, Esq., M.P.
C. D. O. Jephson, Esq., M. P.
William Stuart, Esq., M.P.
Sir Charles Knightley, Bart.

Trustees.

W. R. Keith Douglas, Esq.
Sir Andrew Agnew, Bart., M.P.
Henry Handley, Esq., M.P.

Bankers.

London . .	Messrs. Coutts & Co. Messrs. Smith, Payne, & Smith.
Daventry . .	Messrs. Watkins & Son.
Coventry . .	Messrs. Beck & Prime.
Birmingham .	Messrs. Attwoods & Co.
Liverpool . .	The Bank of Liverpool.
Shrewsbury .	Messrs. Beck, Dodson, & Co.
Northampton .	Messrs. Watkins, Tawney, & Gillett.

Acting Secretary.

A. M. Robertson, Esq., 2, Parliament Street.

Solicitors.

Messrs. Green, Pemberton, Crawley, & Gardiner, Salisbury Square; and E. S. Burton, Esq., Daventry.

Consulting Engineer.

Thomas Telford, Esq.

Acting Engineer.

John Macneill, Esq.

Inspector of Engines.

Alexander Gordon, Esq.

The practicability and economy of employing steam carriages as a means of transport for passengers, upon turnpike roads, having been fully established to the satisfaction of eminent engineers, and scientific gentlemen, who have given their attention to the subject, as appears by the report which accompanies this prospectus*; a company is now forming, to be incorporated under the name of "The London, Holy-

* See page 96.

head, and Liverpool Steam Coach and Road Company."—The capital proposed is 350,000*l.*; to be raised in shares of 20*l.* each.—A deposit of 2*l.* per share to be paid, upon subscribers being recorded as shareholders, and no further sum to be called for, until an Act of Parliament has been obtained.

Although it has been satisfactorily proved that steam carriages are capable of travelling on a well formed turnpike road, with a speed which is unattainable by horses on the same road, yet the attention of the company will be directed to such further improvement of the line of road they have selected, and particularly, in the first instance, to that part of it between London and Birmingham, as will enable locomotive steam carriages to proceed with still greater facility; and it is considered that this object may be attained by a comparatively small investment of capital*.

The estimates of the engineers show in detail the daily charge to be incurred in the hire and wear of carriages, the repair of steam engines, the purchase of fuel, and the payment of engineers and firemen, to which is also added, the expense of the establishments at London, Birmingham, and the depôts, and a sum to be appropriated for the purchase of new engines, amounting, in the whole, to 211*l.* 2*s.* 6*d.* per diem. If to this sum be added interest and profit on the capital, at the rate of 10*l.* per cent. per annum, and a reserved sum for the future repair of the road, the total daily charge, including tolls, will be 375*l.* 17*s.* 6*d.*

Whilst these *estimates of expenditure* have been deduced from calculations of the extreme prices which might by any possibility be demanded and paid for the various works and services required, corroborated by offers of the most respectable tradesmen and manufacturers, as to the terms upon which they would be willing to contract for the supply of the materials and the performance of the work,—*the estimated return* has been calculated, on an assumption that only five hundred daily passengers might travel in the company's carriages;—the average number of persons travelling the same road by the present conveyances, being five hundred and fifty.

The rate of speed at which the company's carriages will travel, will only be limited by a due regard to the safety of the passengers; and it is proposed that the prices of conveyance should be about one-half the present fares by the light coaches.

As these estimates show a profit exceeding 100*l.* per diem, in addition to the interest and profit on the sum expended in road-making, which is to be secured by an additional toll on steam carriages, it has been deemed expedient to present them in fuller detail than has been adopted in any similar prospectus, in order that men of business and experience may the more readily form an idea of the practicability of the measure.

This Company will go to Parliament for a Bill early in the Session of 1834 and 1835.

* *The wood-cut page* 201 *shows the proposed improvement.*

APPENDIX (H).

A Select Committee of the House of Commons, upon the claims of Mr. Goldsworthy Gurney, as set forth in his Petition (see page 101), Reported on the 17th of July, 1834, that they "are only prepared at the present late period of the session to report the minutes of the evidence taken before them; but they earnestly recommend that the enquiry may be resumed early in the next session."

The following is a sketch of the evidence adduced:—

Mr. Goldsworthy Gurney narrates his experimental proceedings to accomplish Locomotion. (These are already pretty fully recorded in chapters III. and IV.) He gives some original opinions upon "Horse Power" as a "term first applied to Steam Engines when the latter were fixed."—"Where the engine itself was not required to move, the term 'Horse Power' deceived the first experimentalists on Elementary Locomotion; they associated with the term, the actual power of a horse under all the circumstances * * because a horse could draw a ton weight and carry himself over the common road, at the rate of from two to three miles an hour, a nominal one-horse steam engine was thought to be able to do the same." "To arrive at the free or disposable power of a horse, at a given useful practical rate of working, as employed in the quick coaches, and smaller carriages, is essential to determine the true political and mechanical value of any engine that is proposed to supersede or compete with it: and secondly, the free or disposable power of the engine at the same rate must also be determined." Mr. Gurney then proceeds to state his observations upon the reciprocating action of weights placed upon upright levers, or props, resting on the ground, and moved alternately forward. "A horse," says he, "rests his body on his legs and propels himself by describing an arc, alternately on them, as levers," the fetlock-joint being the centre. From numerous experiments and calculations, Mr. Gurney believes "the amount of power expended by the horse over our ordinary roads, is equal to about from $\frac{1}{24}$ to $\frac{1}{30}$ of his weight." The steam-carriage mentioned, from pages 82 to 89, was a nominal twelve-horse power, but according to this new computation, the real effect on the road would only be that of a two-horse coach.

The Petitioner next goes into a proof of his losses by contracts destroyed in consequence of the legislative enactments of heavy toll bills (already noticed on page 101), and several witnesses are examined and the contracts are produced and verified.

The evidence given by Mr. Farraday, Dr. Lardner, Mr. John Macneill, and by myself, proves the originality of Mr. Gurney's invention.

Part of my evidence is as follows:—

"Are practical engineers the best persons for introducing this subject?"

"Not, in my opinion, as a body."

"Why?"

"Because they bring their old rules of construction to bear upon a new subject, where those rules will not apply at all. The points which Mr. Gurney has been so particular about, those of circulation and separation, for instance, are not admitted by the body of engineers, and they are, with very few exceptions, inclined still to introduce boilers of a large capacity. If they do so, *some serious accidents must be the consequence*, because there is no plan hitherto devised whereby they can make boilers which have to undergo such changes, perfectly stable; they ought to provide for their bursting; and the provision, of course, should be, that when a boiler does burst, the least harm may result. This can only be obtained by having a boiler of very small chambers."

After examination upon the comparative value and safety of several boilers, I was asked if I had any thing more to state. Still apprehensive of danger from large chambered boilers, I said—

"If any legislative enactment is about to be introduced, I consider that some clause will be necessary to prevent the serious accidents which must attend any attempts to introduce large chambered boilers upon crowded thoroughfares. There is no means yet devised which can secure persons from accident, if a large chambered boiler be suffered to be introduced."

"Do you conceive that there would be any advantage to Mr. Gurney, provided he were to use a larger boiler than you consider safe?"

"I do not think that he would gain advantage by having larger chambers than he has now: his tubes might be increased in diameter with advantage to the circulation, but the chambers of separation, which are the large part of his boilers, need not be made any larger."

"All you wish for is, that there should be public protection with respect to those boilers, so as to keep Mr. Gurney to his machinery as it is at present constructed, and with respect to these chambers?"

"So as to keep Mr. Gurney and other manufacturers within certain limits."

"You do not think that Mr. Gurney's chambers are too large now, but you would object to their being made any larger?"

"I should not like their being made much larger. Mr. Roberts, of Manchester, who is decidedly one of the best mechanics in Europe, lately built a steam-carriage, and after it had run a few miles, it blew up in the streets of Manchester. It had a boiler with large chambers. That no accident has happened upon the Liverpool and Manchester railway, from the large boilers that are there used, must be attributed to the flue tubes, which burst and let out the water. These flue tubes do, in fact, form so many safety-valves. The directors complain of the expense of repairing these tubes, and every means for strengthening them, or for making them more durable, is resorted to. The directors may, however, go on strengthening them so much that they cannot burst in this way. Then accidents from the side of the boiler may be looked for."

About ten days after I had given this evidence, the boiler of Mr. Russell's carriage (see page 120) burst, in consequence of the carriage breaking down near Glasgow, and five lives are stated to have been lost. Such an accident could not have occurred had the boiler been constructed in the manner my evidence would require.

THE END.

BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.
(LATE T. DAVISON.)